Identification and Profiling of Hazards

Risk Assessment FEMA Requirements
Requirement §201.6(c)(2): Plan content. The plan shall include the following:
(2) A risk assessment that provides the factual basis for activities proposed in the strategy to reduce losses from identified hazards. Local risk assessments must provide sufficient information to enable the jurisdiction to identify and prioritize appropriate mitigation actions to reduce losses from identified hazards.

This plan is an update of the 2004 City of Redmond Hazard Mitigation Plan (HMP). Although it is an update, this document has been redesigned so that it looks, feels, and reads differently than the original. This is due to several factors: new hazard information has become available that drives new definitions of risk, the City has matured and new capabilities are now available, and the new format will allow readers to more easily understand the content. In addition, the 2004 HMP included several action items that have been completed, creating an opportunity for developing new mitigation strategies.

It is critical that risk assessment, mitigation and preparedness efforts are founded on accurate information. This section of the plan assess the potential threats to the City of Redmond – earthquakes, severe storms, flooding, wildfires, landslides, pandemics, heat waves, droughts and hazardous materials spills – and the corresponding vulnerabilities. The risks have been identified based on historical events and available information about changing conditions. Changes in land use and climate change were researched in order to provide a valuable assessment of how these risks may vary from the historical patterns.

The City of Redmond and King County GIS databases were used to determine the potential impact of each hazard on the critical infrastructure and city services. Historical data and climate change predictions were used to identify the likelihood that the identified hazards would affect Redmond in the future.

The first round of screening looked at a wide variety of hazards that are probable in the United States. Through this screening, the project team identified the significant risks for Redmond. The Risk Assessment Model (described below) was used to determine the relative risk of each hazard based on the location, frequency and vulnerabilities. Three likely scenarios were written in order to illustrate the probable sequence of events. In order to understand the likely risks, each hazard was profiled considering the location, timing/duration, severity, frequency, vulnerabilities and future planned development.

Hazards Screening for the City of Redmond		
HAZARD	**RISK**	**WHY / WHY NOT**
Avalanche	None	Does not affect City
Coastal Erosion	None	Does not affect City
Coastal Storm	None	Does not affect City
Drought	Low Risk	Risk may increase in future with climate change
Earthquake – Crustal	High Risk	Low frequency, highly destructive
Earthquake – Benioff	High Risk	Moderate frequency, moderately destructive
Earthquake – Subduction	High Risk	Low frequency, highly destructive
Extreme Heat	Low Risk	Risk may increase in future with climate change
Flood	High Risk	Risk may increase in future with climate change.
Hazardous Material Spill	Low Risk	Hazardous Materials are highly regulated
Hurricane	None	Does not affect City
Landslide	Low Risk	Risk may increase in future with climate change and increased development
Pandemic	Low Risk	Risk may change or increase in future with climate change and globalization
Seiche	Low Risk	May be a secondary hazard (addressed as part of landslides)
Tornado	None	Does not affect City
Tsunami	None	Does not affect City
Volcano	None	Does not affect City
Wildfire	Low Risk	Risk will increase in future with climate change
Winter Storm	High Risk	Risk will increase in future with climate change

Table 9: Hazards Screening for the City of Redmond

Significant Risks

- Benioff Earthquake and Liquefaction
- Severe Storms
- Floods
- Crustal / Subduction Earthquakes and Liquefaction

Less Significant Risks

- Landslide
- Drought

Risks Monitored by an Outside Agency

- Pandemic (WHO and CDC)
- Hazardous Materials Spill (EPA)

Emerging Risks Due to Climate Change

- Wildfires
- Heat Wave

The City of Redmond is exposed to a number of natural hazards that vary in potential intensity and impact on the City. This plan addresses four hazards that pose a significant threat and six that pose limited threats. Of the six that pose limited threats, two are primarily monitored by an outside agency and two are emerging risks that are likely to pose a greater threat to Redmond in the future.

Risk Assessment FEMA Requirements
Requirement §201.6(c)(2): Plan content. The plan shall include the following:
(2)(i) A description of the type, location, and extent of all natural hazards that can affect the jurisdiction. The plan shall include information on previous occurrences of hazard events and on the probability of future hazard events.

Hazards were included in the plan based on the likelihood of occurrence and the potential impact on the City. Vulnerabilities considered include people, buildings, systems, the local economy, and the natural environment. Although heat related hazards do not currently present a significant hazard in Redmond's mild climate, climate change predictions indicate that these hazards may be more significant in the future. In addition to considering the hazards independently, the plan addresses the likelihood that one event may trigger secondary hazards or exacerbate existing conditions.

The hazards included in this plan were identified through academic research and community input. The MIC (Mitigation Implementation Committee) provided local expertise and historical knowledge to the Project Team, which subsequently conducted extensive research. The list of hazards includes all those that pose a potential risk to the City of Redmond.

Risk Assessment Model

In order to comprehensively assess the relative risk posed by hazards, the Project Team developed a model that considers both the frequency and vulnerability to the hazards. The objective of the rating system is to identify which hazards pose the greatest risk to the City of Redmond. In order to comprehensively assess the relative risk, the model considers the frequency and the vulnerability of each hazard. The model deals with hazards and risk in a relative manner and the risk rankings are to be considered within this context. Frequency and vulnerability were given equal weighting. Specifically, the model uses the following simplified equation:

Risk = Frequency x Vulnerability Factor

Frequency

The hazard frequency was determined for each hazard using a 0-3 scale:

0	Hazard is unlikely to ever occur in Redmond
1	Hazard may occur once in a generation
2	Hazard may occur every ten to fifty years
3	Hazard will occur with some regularity

Vulnerability Factor

A vulnerability factor was used to address the various vulnerabilities and the severity of a hazard. The built environment, systems (transportation, utilities, economy, etc.), natural systems, the human population and severity were each assigned a zero to three value. In order to equally weight frequency and vulnerability, the average of the vulnerabilities provided a "vulnerability factor." The vulnerability ratings used the following equation:

Vulnerability Factor = (Human + Built + Natural + Systems + Severity)/5

The vulnerability factor was then classified on a 0-3 scale:

0	The vulnerable population or system will not be affected
1	Event causes some mild disturbances to some systems, buildings, natural environment or populations
2	Event causes some mild disturbances to all systems, buildings, natural environment or populations OR event causes severe disturbance to some systems, buildings, natural environment or populations
3	The entire City is significantly affected by the event

Based on the information provided about each of the hazards, the assessment used the following equation to complete the Hazard Rating Chart:

Risk = Frequency x ((Human + Built + Natural + Systems + Severity)/5)

Due to the variability inherent in each of the hazards and the rating system, the risks were divided into categories of low, moderate and high-risk hazards. The relative ranking established by this model provided a framework for the risks and strategies addressed in the Hazards Mitigation Plan.

The hazards ranked in 2004 have changed only slightly in 2009. Severe storms and earthquake remain the primary hazards Redmond must be concerned with. Climate change has been incorporated into the risk assessment in 2009 and that has resulted in a little shifting of the order of hazards. The biggest change has come with the rise of epidemic/pandemic on the list. In 2004, pandemic ranked eighth out of ten items. In 2006, pandemic was listed second on the hazards list. In 2009, it ranks at the top of the lower half of the list.

Table 10, Redmond Risk Assessment Model, shows the Risk Assessment as applied to the hazards applicable to Redmond.

Event	Frequency	Vulnerability					Vulnerability Factor	Risk Rating	Risk Level
		Built	Natural	Systems	Population	Severity			
Possible Rankings	0 - 3	0 - 3	0 - 3	0 - 3	0 - 3	0 - 3	0 - 3	0 - 9	Low-High
Severe Storms	3	1	1	3	2	2	1.8	5.4	High
Benioff Earthquake	2	2	1	2	2	2	1.8	3.6	High
Floods	2	2	2	1	1	2	1.6	3.2	High
Crustal / Subduction Earthquake	1	3	1	3	3	3	2.6	2.6	High
Wildfire	1	2	2	1	1	2	1.6	1.6	Low
Landslide	1	2	0	2	1	2	1.4	1.4	Low
Pandemic Mild	2	0	0	0	2	1	**0.6**	**1.2**	Low
Pandemic Catastrophic	1	0	0	0	3	3	**1.2**	**1.2**	Low
Heat Wave	1	0	2	0	2	2	1.2	1.2	Low
Drought	1	0	2	1	2	1	1.2	1.2	Low
Hazardous Materials	1	0	1	1	0	2	**0.8**	**0.8**	Low

Table 10: Risk Assessment Model

Scenarios

Scenarios provide a narration of events that are likely to occur in Redmond. Each scenario considers the threat of the hazard and the probable subsequent events that will occur based on the current conditions. Three scenarios were developed to look at regional, municipality-wide and localized events. These scenarios were developed to help illustrate identified vulnerabilities and facilitate public participation. The HAZUS software package produced by FEMA was used to predict the impacts of Scenario 1: Crustal Earthquake.

Scenario 1: Crustal Earthquake[16]

At 1:38pm on March 18th a 6.7 magnitude earthquake occurs along the Seattle fault. The epicenter is located within two miles directly south of Redmond. Peak Ground Acceleration (PGA) ranged from 0.35 in the Northern end of the City to as high as 0.51 in the Southern edge of the City. The massive shaking caused over $980 million of damage and 57 casualties.

The magnitude of the earthquake was similar to the 2001 Nisqually earthquake, but the violent ground shaking caused much more damage. The earthquake caused damage to 5,547 of the City's 17,000 buildings. 271 of those buildings are damaged beyond repair. 47 of the 52 unreinforced masonry buildings were at least moderately

16 Scenario and damage is based on HAZUS run of 6.7 magnitude earthquake on the Seattle Fault. The region was defined as the main census tracts within the City of Redmond. Consequently, the numbers of buildings, population, etc. are not completely consistent with City specific data.

damaged. The total cost of damages to the buildings exceeded $806 million. Transportation systems within the City of Redmond also sustained damage. Two bridges were damaged, but one regained functionality after the day of the event. The total cost of damage to the transportation system was over $30.2 million. Regional transportation failures, such as the collapse of the SR 520 bridge, limited Redmond's access to regional facilities that were already overwhelmed.

Lifeline utilities were also damaged. On the day of the earthquake, 231 leaks and 58 breaks in the water lines left over 8000 households without access to potable water. Service was promptly restored within 72 hours. Additional leaks and breaks in the wastewater sewer lines caused additional complications.

11,501 households lost electricity. Within a week, only 2,367 households remained without power. By April 18th only 406 households were still without electricity.

In addition to the immediate damage of the earthquake, fires broke out across the City and caused an additional $13 million of damages. The five small fires burned less that a tenth of a square mile and displaced 148 people.

The biggest problem has been the lack of a local medical facility and the fact that the regional hospitals were overwhelmed. There were 620 people who suffered minor injuries that did not require hospitalization. Another 177 suffered non-threatening injuries that did require hospitalization. There were 29 people who had serious injuries that required immediate care. The earthquake caused 57 fatalities.

Scenario 2: Winter Storm

Snow began falling heavily at 1 a.m. on January 7th and continued in periodic showers for 8 days, depositing a total of 2 feet of precipitation. When the snow stopped on January 15th, the accumulation on uncleared roads averaged 10 inches, with drifts up to 3 feet. The snow and sleet covered the streets with icy snow patches. Sidewalks were invisible under the snow and there were several instances of pedestrian and vehicular paths crossing, resulting in 36 minor accidents and 5 major accidents with 3 traffic-related fatalities. The City's power grid had several temporary shutdowns and repairs, but was consistently off from midnight on January 13th to 3 p.m. on January 15th. Emergency call volumes during this period were very high, with the majority of calls requiring the evacuation of elderly homeowners to hospitals in Bellevue.

High volumes of snowfall caused ceiling leakage and some buckling on 36 commercial and office buildings with flat roofs, causing approximately $1 million in damaged equipment and repair costs. Storm drains overflowed in several areas from debris, snowpack, and frozen water, and an ice jam on the Sammamish River flooded parts of West Lake Sammamish Parkway NE at the 520 off ramps, causing major traffic delays for 8 hours on the 14th. Many citizens were unable to drive and large numbers of businesses were closed for several days. Roads that were cleared were congested with triple the usual numbers of traffic due to impassible roads elsewhere. A family

of four died of carbon monoxide poisoning after bringing a generator into their home, and 10 house fires from candles and woodstoves caused above the usual amount of damage, due to delayed response times caused by poor road conditions. Businesses in the food industry, particularly grocery stores, discarded over 6 tons of rotting perishables. The loss of electricity compromised the most common of communication systems, making standard lines of communication unavailable, including RCTV and the internet. Several businesses sought additional loans to cover company-wide vacation time and loss of revenue and inventory; three small businesses declared bankruptcy.

Scenario 3: Landslide

At 10 p.m. on November 5th, after several weeks of rain, a section of hillside in the Education Hill area gave way. Three homes slid fifty feet down the hillside, depositing debris in the backyards of several other homes, which were not damaged directly but lost landscaping and auxiliary structures (e.g. storage sheds). The residents and the City are cleaning up the large amounts of debris. Five people were injured, but there were no life-threatening injuries. Although neighboring homes are currently stable, monitoring will continue as the section that gave way continues to occasionally crumble. The road above the hill has been closed due to instability. The debris blocked a culvert at the bottom of the hill and caused two feet of flooding on sections of SR-202, Redmond-Woodinville Road. The road was closed for thirty-six hours before crews were able to restore normal traffic flow.

Climate Change

Governor Gregoire and the State of Washington, in recognition that our climate is changing and the impacts of the expected changes could be profound, have instructed us to significantly reduce the State's contributions to climate change. - *Washington Climate Change Challenge* (*Executive Order 07- 02*).[17]

In the report "The Preparation and Adaptation Working Groups" (PAWG) our Governor is asking us to incorporate climate change and its impacts into planning and decision-making processes. Accordingly, this Plan will address the impacts of climate change.

As a result of extensive research done by the International Panel on Climate Change and University of Washington Climate Impact Group[18], we know that Washington's climate is changing, and the impacts of these projected changes will be far reaching. Although our state is working to significantly reduce its contributions to climate change, some changes cannot (or will not) be prevented. For Redmond, expected changes include:

- Hotter, drier summers
- Wetter winters with increasing rainfall and rain intensity
- Increases in weather extremes
- Secondary hazards include increased chance of wildland/urban interface fires, heat waves, insect infestation, drought, potable water shortages, flooding, erosion and landslides.

Scientists expect the Pacific Northwest climate to warm approximately 0.5˚F every ten years over the next several decades. This rate is more than three times faster than the warming experienced during the twentieth century. In Washington, scientists project that average annual temperatures will be 1.9˚F higher by the 2020s when compared with the 1970-1999 average, and 2.9˚F higher by the 2040s. Changes in total precipitation are not projected to be significant over that time period; however, patterns of precipitation will change. Winters will bring more rain and less snow in the mountains.[19]

These projections are based on calculations that take into account human contributions to the accumulation of greenhouse gasses. Being human-caused, these projections could be tempered, should efforts be made at reducing greenhouse contributions.[20] While such efforts could slow warming, the impacts would continue for some time.

17 http://www.governor.wa.gov/execorders/eo_07-02.pdf
18 Global Climate Change Impacts in the United States, Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.). Cambridge University Press, 2009.
19 Ibid.
20 http://www.governor.wa.gov/execorders/eo_07-02.pdf

Severe Storms Risk Assessment

This plan is an update of the 2004 City of Redmond Hazard Mitigation Plan (HMP). Although it is an update, this document has been redesigned so that it looks, feels, and reads differently than the original. This is due to several factors: new hazard information has become available that drives new definitions of risk, the City has matured and new capabilities are now available, and the new format will allow readers to more easily understand the content. In addition, the 2004 HMP included several action items that have been completed, creating an opportunity for developing new mitigation strategies.

4.1 Identifying Severe Storm Hazards

Severe local storms are categorized by atmospheric disturbances, with cold temperatures and various forms of precipitation. In Redmond's typically mild climate, irregular severe storms include high winds, freezing rain, sleet, heavy snowfall or hail. Some severe storms are accompanied by thunder and lightening. Since Redmond is not mountainous, six or more inches of snow in a 24-hour period is considered severe.

The following list shows the number of days with measurable amounts of snow and rain in the previous eight years in the City of Redmond.[21] A measurable amount of precipitation is at least 0.01" of rain and ice or 0.1" of snow.

Annual Counts of Days with Measurable Snow and Rain		
Year	**Snow**	**Rain**
2008	10	175
2007	7	190
2006	4	186
2005	3	174
2004	3	167
2003	2	180
2002	7	160
2001	0	182
2000	5	166
1999	0	183

Table 11: Annual Count of Days with Measurable Snow and Rain
Source: Office of the Washington State Climatologist, Temperature data from 1999-2008, Courtesy of Karin Bumbaco, Assistant State Climatologist.

The trajectory of these systems determines the local effect. Storms with a southern origin bring heavy rain. Storms coming from the north bring cold air and the potential for snow and ice. Any winter storm, regardless of its trajectory, can be accompanied by high winds. Storms with sustained winds above 30 mph generally cause low impact, widespread damage, while winds above 50 mph are powerful enough to

21 Office of Washington State Climatology. http://www.climate.washington.edu/climate.html

cause significant damage.

Climate change predictions indicate that storms in the Northwest are likely to occur more frequently and be more severe. Although Redmond does not typically experience more than a week of snow each year, it is likely that these events will become more common. Redmond can expect to receive more ice and snow in the winter months.

4.2 Profiling Severe Storm Hazard Events

A. Location

The entire City of Redmond may be affected by a severe storm; however, microclimates within the City may increase the vulnerability in specific areas. Narrow culverts are vulnerable to ice jams and hilltops are subject to lightning. The hill and valley topography creates several wind tunnels. Steep slopes increase the likelihood that Rose Hill and Education Hill will experience more adverse effects of a severe storm.

B. Timing and Duration

Most severe storms in Redmond occur between November and April when the jet stream[22] moves over the West Coast, and Pacific low-pressure systems are more frequent.[23] Storms can last anywhere from a few hours to several days. Weather forecasting abilities will provide Redmond, at minimum, a few hours warning prior to an extreme weather event.

C. Severity

Storms in Redmond are likely to have a severity of low to moderate. Historically, storms have been relatively short in duration and have had mostly localized impacts. The main concern about a severe storm in Redmond is the potential to isolate citizens and businesses if roads are blocked by snow or ice. This may cause some financial hardships for the City, but it is unlikely to cause widespread, permanent damage or loss of life.

D. Frequency

Although Redmond does experience some days with temperatures below freezing and receives some snow, severe weather is not typical of Redmond winters. The proximity to the Puget Sound keeps the climate moderate, with some incidents of snow. Over the last 20 years, Redmond has experienced an average 3.1 inches of snow per year. During that period, the most snow recorded in one month was 17.9 inches. There has not been a month with an average daily minimum temperature below freezing.[24]

22 Jet streams are relatively narrow bands of strong wind in the upper levels of the atmosphere. The winds blow from west to east in jet streams but the flow often shifts to the north and south. Jet streams follow the boundaries between hot and cold air. Since these hot and cold air boundaries are most pronounced in winter, jet streams are the strongest for both the northern and southern hemisphere winters.

23 National Weather Service, "JetStream - Online School for Weather," http://www.srh.noaa.gov/srh/jetstream/global/jet.htm.

24 Western Regional Climate Center, "National Weather Station 457470 for period 1986 to 2000," http://www.wrcc.dri.edu/.

Redmond experiences high winds (with velocities of 50 mph) approximately once every two years. Winds that exceed 60 mph occur approximately once every 50 years. King County has reportedly experienced at least one serious windstorm per calendar year.

Previous Occurrences
The last significant windstorm to affect the City of Redmond occurred in 2006. In the Seattle region, hundreds of thousands of homes remained without power for several days after the storm. The lack of heat forced many residents to leave their homes and seek shelter in hotels or emergency facilities. The power outages closed many businesses, even Microsoft shut down large portions of its Redmond campus.[25]

The last major winter storm was in December 2008, when the City received almost nine inches of snow in one day. The snow limited the ability of people and services to move around the City. Police officers had difficulty responding to calls in some neighborhoods. Garbage collection suspended service for 11 days. The Old Redmond Schoolhouse Community Center, Redmond Senior Center and Old Fire House Teen Center were closed Dec. 18-26, and City offices officially closed for two days.[26]

Probability of Future Events
Reports from the International Panel on Climate Change and the University of Washington Climate Impact Group confirm that the region's climate is changing and that the impacts will be far reaching. The City of Redmond can expect an increase of severe storm events in the future.

While changes in overall annual precipitation are not projected to be significant, the timing and character of precipitation is projected to change. Winters will bring more rain and less snow in the mountains. Summers will generally tend to be dryer, increasing susceptibility to flash floods as a secondary hazard to severe summer rainstorms. In addition, the probability of secondary hazards will increase, including saturated soil hazards such as landslides and falling trees.

4.3 Assessing Severe Storm Vulnerability

4.3.1 Overview

Due to a typically mild climate, Redmond is vulnerable to severe storms. Ice, snow and strong winds can damage infrastructure, isolate citizens and limit access to essential services. Although storms may cause some structural damage, the main vulnerabilities to a severe storm are systems and populations that may not be able to withstand temporary isolation or limited transportation.

25 Scott Sistek, "The craziest year ever for weather?" Komo News, January 1, 2007, http://www.komonews.com/news/local/5051876.html.
26 Mary Stevens Decker, "City looking to improve winter storm response plan," *The Redmond Reporter*, *http://www.pnwlocalnews.com/east_king/red/news/37461739.html.*

4.3.2 Profiling the Vulnerabilities

A. Man-made

The majority of the building stock in Redmond will be able to withstand the impacts of a snow, wind or ice storm. However, the vulnerability to such a storm varies by the location and the type of structure. Buildings located on hilltops are more vulnerable to lightning and those located on steep slopes are vulnerable to landslides. Flat-roofed buildings and other structures that accumulate snow may be susceptible to collapse under heavy snow.

B. Natural

Severe storms impact the natural environment by increasing stormwater runoff, as well as increasing flooding and tree displacement. Such alteration of the natural environment will impact fish and wildlife habitat. However, these are natural processes; absent prolonged climate changes, animals and their ecosystems are resilient to temporary changes in weather. However, severe storms may have an impact on species and habitats that are already stressed. For example, increased runoff could increase the saturation rate of soils, thus increasing the likelihood of downed trees in high wind. Sand on roadways to provide friction on icy surfaces may create sedimentation problems in local streams and rivers, thereby affecting salmon habitat.

The critical areas likely to be affected by severe storms are fish and wildlife habitat and wetlands. Redmond has more than ten different areas containing sizable wetlands.[27] At least 19 species of birds and six species of mammals are found within the wetlands in City of Redmond. See **Map 8, City of Redmond Wetlands** for the location of wetlands in Redmond.

Additionally, Redmond is home to endangered salmon. The Salmon Habitat Recovery Plan for Water Resource Inventory Area 8 recommends restoring floodplain connectivity and channel meander as well as riparian forest and large woody debris to the Sammamish River channel.[28] These aspects of the waterways in Redmond could all potentially be disrupted by severe storms.

C. Systems

Roads in Redmond are vulnerable to severe storms. Excess precipitation is likely to limit access and isolate citizens, but it is unlikely to cause major permanent damage to the transportation network. Heavy rain, ice or snow may make roads impassible or limit visibility to the extent that driving is not safe. Although the City does have a snow/ice removal plan, large residential sections of the City, particularly in the North Redmond and Education Hill neighborhoods, may not have vehicular access until the snow/ice melts. **Map 5, City of Redmond Motorized Transportation Network**, shows the road network in Redmond.

27 *SAO Wetland Wilderness Lookup Table, King County Dept. of Environmental Services, Paul McCombs, GIS Data Team Lead, KCGIS Center.*

28 WRIA 8 Coordination Team, Lake Washington/Cedar/Sammamish Watershed, "Final Lake Washington/Cedar/Sammamish Watershed (WRIA 8), Chinook Salmon Conservation Plan," http://www.govlink.org/watersheds/8/planning/chinook-conservation-plan.aspx, 2007.

Redmond has put most of the power lines underground; however, the remaining above-ground lines are vulnerable to high winds, ice and heavy snow. Additionally, heavy rainfall may loosen soils, making power poles and towers more susceptible to failure in high winds.

Water supply and sewer facilities may be vulnerable to severe storms with massive rainwater that quickly accumulates. Stormwater drains and culverts may overflow during a heavy rain event and cause flooding.

Power outages and limited accessibility may force businesses to temporarily shut down. These unexpected closures can result in large financial losses. Loss of power can cause large product losses for food service businesses. Since businesses operate within an inter-connected system, the closure of one may have large impacts on other businesses in the area. Smaller businesses may not be able to recover from the loss of business or damages caused by a severe storm.

Severe storms can leave residents completely isolated and without access to emergency assistance. Currently there are no hospitals in Redmond. Road closures may prevent residents that require significant medical care from access to necessities.

D. Populations

Isolated Populations
Residents of Redmond living on steep slopes, or areas accessed only by a steep slope are vulnerable to isolation during a heavy snow or ice event. Downed trees and power lines will further restrict mobility. People living in areas that are accessed only by one road may also become isolated in a severe storm. Each of Redmond's three hills may be isolated for several days.

Persons with Disabilities
Persons with disabilities may not be able to access vital services due to road closures. People with medical devices that require constant electricity are vulnerable to a power outage.

Children
Children may need to be reunited with parents, if road closures occur once they are separated (such as during the school day). **Map 7, City of Redmond Community Facilties**,shows the location of several types of community facilities, including schools. Children are likely to be concentrated in these areas if the events occur during a school day.

Elderly
Elderly people with compromised immune systems are particularly vulnerable to the cold if there is a power outage in the winter. Additionally, they may not be able to

access emergency medical facilities. People who rely on electricity for medical devices will be especially vulnerable. **Map 9, City of Redmond Concentration of People 65 Years or Older and Retirement Home Locations** shows the location of retirement homes; elderly housing facilities are highly concentrated within Redmond.

Limited English Language
Power outages may be particularly isolating to limited English language speakers, as non-English speakers face additional challenges when accessing emergency information. **See Map 10, City of Redmond People with Limited English Language Capability**, for the location of people that speak limited English.

Low-income Residents
According to an income analysis shown in **Map 11, City of Redmond Median Income by Block Group**, the majority of Redmond's low-income population is located on the edges of the City, furthest from services and resources. These residents may have limited transportation options and minimal financial capabilities in a severe storm. Absence from work due to isolation will be an additional burden for limited income households.

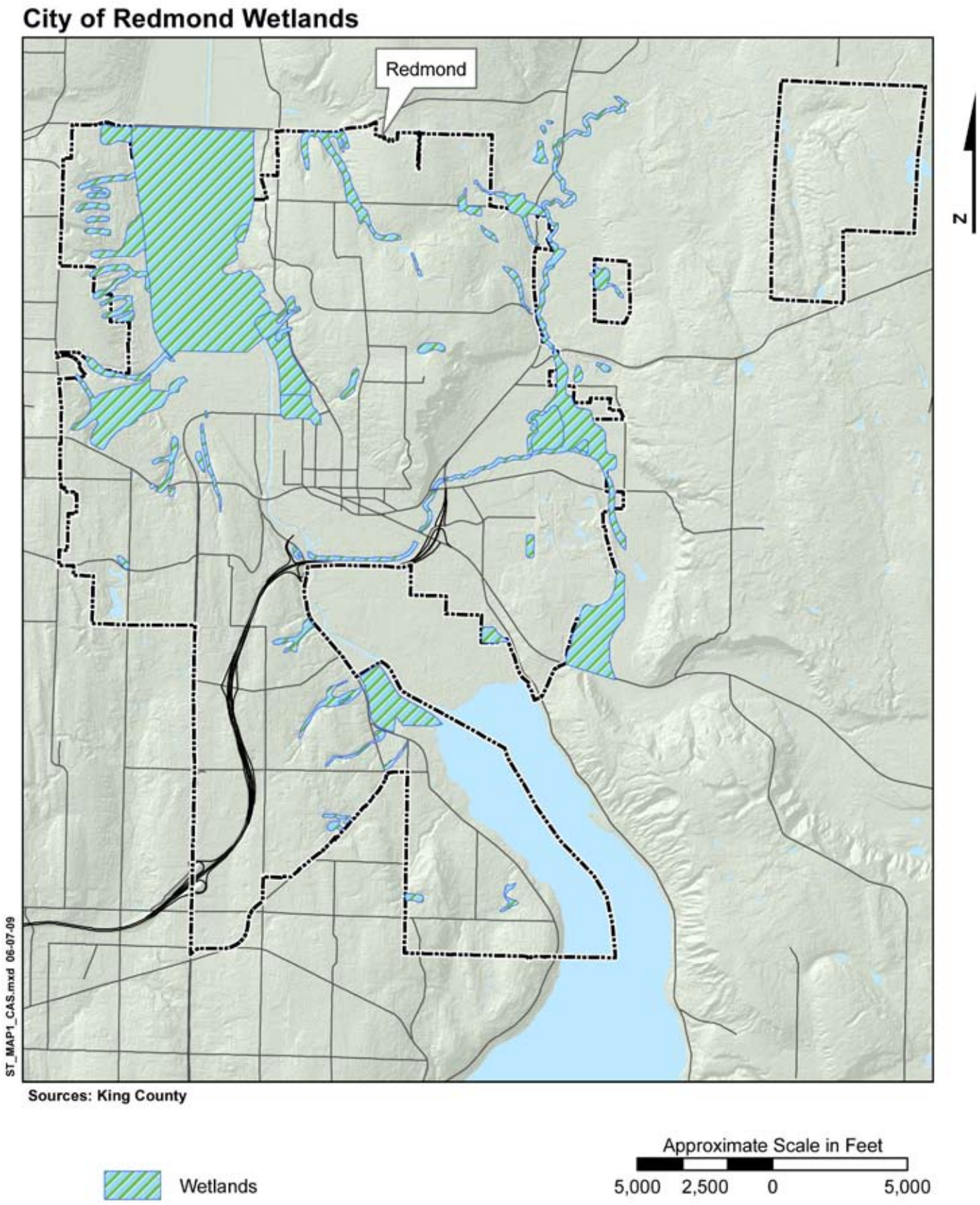
4.3.3 Analyzing Development Trends

New residential expansion on the edges of town increases the number of people that are likely to become isolated during a severe storm. The lack of neighborhood-commercial land use in these neighborhoods show that there will be limited, if any, additional private capabilities to provide services during a storm. Small commercial facilities in residential areas could assist in distributing goods and services or they could simply provide a psychological break for isolated residents.

The Future Land Use Map (FLUM) shows that the City is concentrating growth in central areas such as Downtown and Overlake; this development will reduce the risk of isolation. Similarly, increased density will ensure better access to emergency facilities and resources.

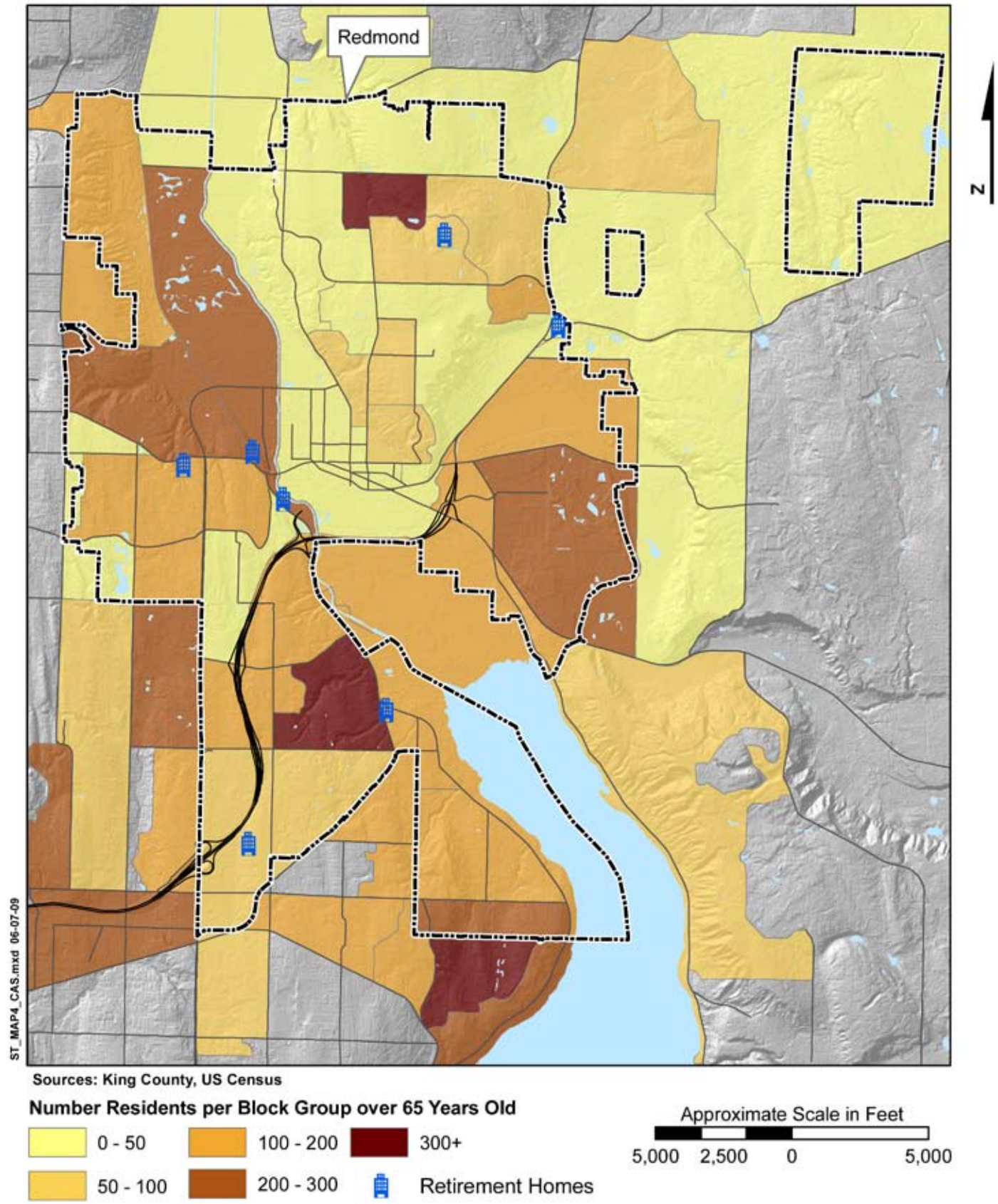
4.4 Scenario

See Scenario 2 in the Part 3 Introduction.



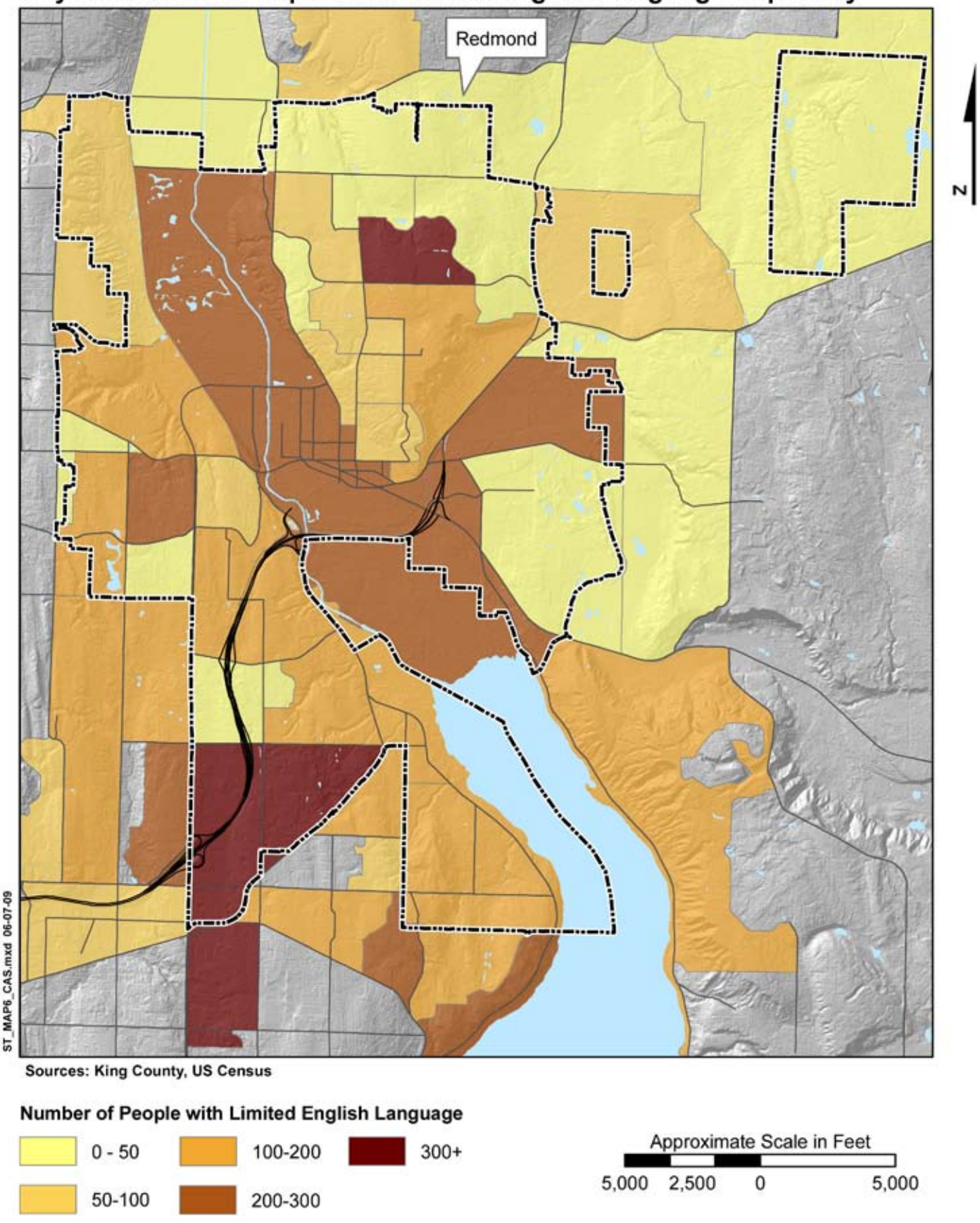
Map 8: City of Redmond Wetlands

City of Redmond Concentration of People 65 Years or Older and Retirement Home Locations

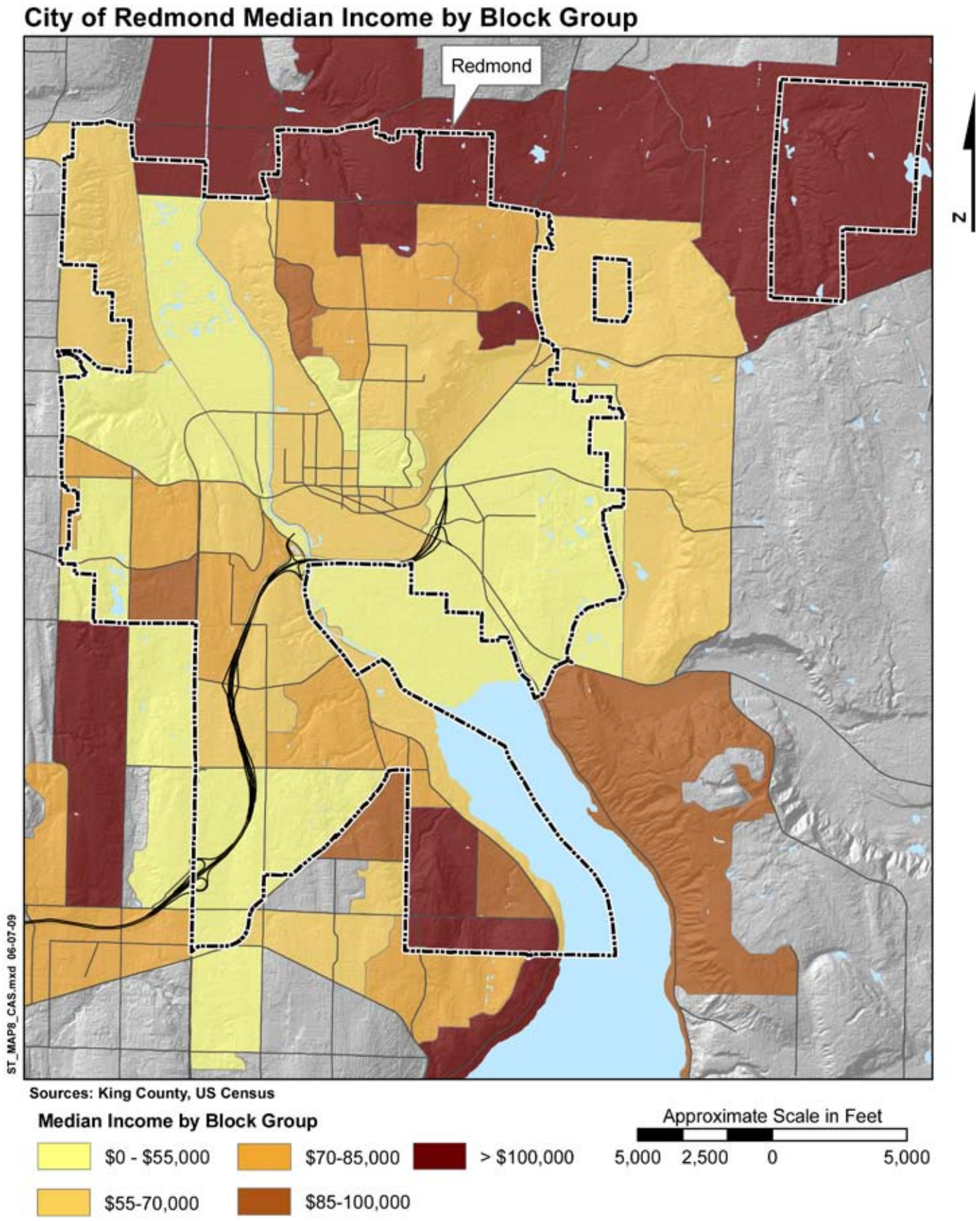


Map 9: City of Redmond Concentration of People 65 Years or Older and Retirement Home Locations

City of Redmond People with Limited English Language Capability



Map 10: City of Redmond People with Limited English Language Capability



Map 11: City of Redmond Median Income by Block Group

Earthquake Risk Assessment

This plan is an update of the 2004 City of Redmond Hazard Mitigation Plan (HMP). Although it is an update, this document has been redesigned so that it looks, feels, and reads differently than the original. This is due to several factors: new hazard information has become available that drives new definitions of risk, the City has matured and new capabilities are now available, and the new format will allow readers to more easily understand the content. In addition, the 2004 HMP included several action items that have been completed, creating an opportunity for developing new mitigation strategies.

5.1 Identify Earthquake Hazards

Earthquakes are vibrations caused by the movement of the Earth's crustal plates. The Earth's crust is, on average, approximately 45 miles thick and consists of several plates that slide over a partially molten layer of the planet.[29] The Pacific Northwest, including Redmond, is located in a subduction zone, characterized by oceanic plates sinking underneath continental plates.[30] In subduction zones, the crust builds up tension, which eventually releases with violent force. The resulting vibration causes distortion and uplift of the surface crust and may be extremely damaging.

The City of Redmond has a 0.2% chance that an earthquake with a peak horizontal acceleration of 0.25 G will occur in any given year (see **Map 13, City of Redmond Probabilistic Seismic Risk**).[31] A G is the average acceleration produced by gravity at the earth's surface (9.80665 meters per second squared). This measurement describes ground shake during earthquakes.

The Puget Sound Region and Redmond are at risk of earthquakes from three sources:[32]

- The Juan de Fuca plate is subducting underneath the North American plate.
- The Seattle Fault, located a few miles south of Redmond
- The South Whidbey Fault, located north of Redmond

Soil Liquefaction and Ground Shaking

Soil liquefaction and intense ground shaking often cause the most damage during an earthquake. Liquefaction occurs when strong earthquake shaking causes an immediate weakening of soils such that the soils take on properties similar to quicksand. Liquefaction most often occurs in artificial fill, and in highly saturated loose and sandy soils, such as low-lying coastal areas, lakeshores, and river valleys.

29 David Hyndman and Donald Hyndman, Natural Hazards and Disasters 2006 Update (Belmont, CA: Thomson Brooks/Cole, 2006).
30 Lynn S. Fichter, "Plate Tectonic Theory: Plate Boundaries and Interplate Relationships," James Madison University Department of Geology & Environmental Science.
31 Earthquake Hazards Program, "National Seismic Hazard Maps-2008," U.S. Geological Survey, http://gldims.cr.usgs.gov/nshmp2008/viewer.htm.
32 Michael A. Fisher et al., "Crustal Structure and Earthquake Hazards of the Subduction Zone in Southwestern British Columbia and Western Washington," U.S. Geological Survey, http://pubs.usgs.gov/pp/pp1661c/pp1661c.pdf.

Susceptibility to liquefaction is measured by the physical characteristics of a soil, such as grain, texture, compaction, and depth of groundwater.[33]

Glacial till covers 60 to 70 percent of the City of Redmond, and is nearly impermeable due to its compact nature and scarcity of organic matter.[34] Deposited alluvium, found in Redmond, is made up of fine particles of silt and clay and larger particles of sand and gravel. According to the United States Geologic Survey (USGS), the seismic stability of alluvium is very poor, and the seismic stability of other post-glacial materials is very poor to fair.[35] The Sammamish River Valley that runs through Redmond is vulnerable to liquefaction during an earthquake.

Earthquake-induced ground shaking is strongest in river valleys and other soft-soil shorelines – conditions common throughout the City of Redmond (see **Map 14, City of Redmond Soil Liquefaction Hazard**). Ground shaking in soft soils layered on stiffer soils or rock is more severe than in areas with little variation between layers. The severity of soil-related natural hazards and ground failure phenomena often depends on status of groundwater, soil saturation, and drought conditions.[36] Soils prone to liquefaction and amplified ground shaking will present the most severe hazards.

Secondary Hazards

A significant earthquake in the Puget Sound Region is likely to cause any of the following secondary hazards:[37]

- Liquefaction
- Landslides
- Tsunamis
- Seiche (a large displacement sloshing of water in a lake, such as Lake Sammamish, causing tsunami type damage)
- Building failure due to structure age and building construction
- Fires from downed power lines, gas or electrical equipment malfunctions
- Hazardous materials spills

A severe earthquake on the South Whidbey Fault may cause activity on other faults.[38]

5.2 Profiling Earthquake Hazard Events

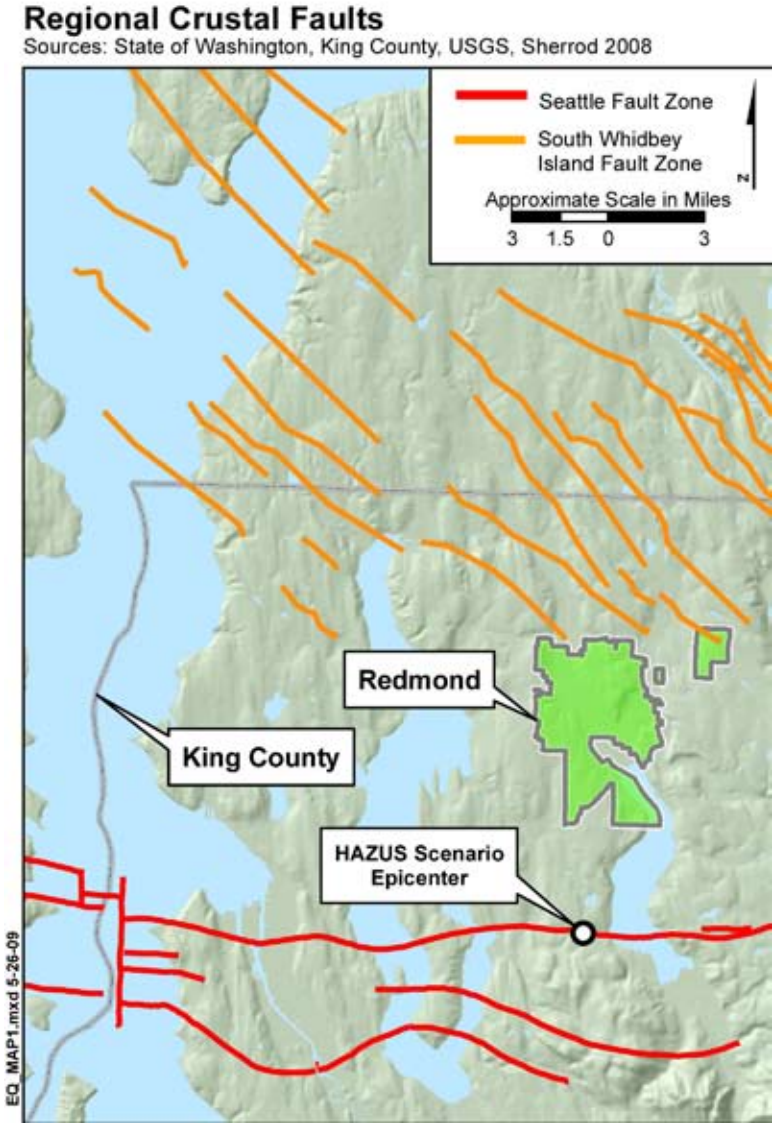
There are three types of earthquakes that occur within the Puget Sound Region:

33 Jorgen Johansson, "Soil Liquefaction Web Site," University of Washington Department of Civil Engineering, http://www.ce.washington.edu/~liquefaction/html/main.html.
34 Tracy Chollak and Paul Rosenfield, "Guidelines for Landscaping with Compost-Amended Soils," City of Redmond.
35 Mineral Information Service, "The Seattle Earthquake of April 29, 1965," California Geology 18, no. 7 (1965).
36 Jorgen Johansson, "Soil Liquefaction Web Site," University of Washington Department of Civil Engineering, http://www.ce.washington.edu/~liquefaction/html/main.html.
37 Cascadia Region Earthquake Workgroup, "Subduction Zone Earthquakes: A Magnitude 9.0 Earthquake Scenario, 2005," http://www.crew.org/papers/CREWCascadiaFinal.pdf.
38 Gale Fiege, "South Whidbey Fault Has Potential For Major Quake," The Daily Herald, June 15 2009, http://www.heraldnet.com/article/20090615/NEWS01/706159921.

subduction zone earthquakes, Benioff (deep) earthquakes, and crustal (shallow) earthquakes.[39] These types of earthquakes differ in location, timing and duration, severity, and frequency. Each type of earthquake is profiled individually.

Location of an earthquake is described by the focus and the epicenter. The focus is the first point of movement along the fault line. The epicenter is the corresponding point above the focus at the Earth's surface.

The severity of an earthquake depends on the intensity of surface shaking (peak ground acceleration) and potential damage to the built environment. Severity is commonly measured with the Modified Mercalli Scale or the Richter Scale (Table 12). The City of Redmond is at greatest risk of large, shallow, crustal earthquakes emanating from the Seattle or South Whidbey faults (see **Map 12, Regional Crustal Faults**).



Map 12: Regional Crustal Faults

5.2.1 Subduction Zone Earthquakes

A. Location

Subduction zone earthquakes are caused by the Juan de Fuca Plate sliding beneath the North American Plate. Currently, The Juan de Fuca Plate is sinking below the North American Plate at a rate of approximately 4.5 cm per year. This subduction zone is approximately 200 miles off the Washington coast.[40] This type of earthquake will affect the entire region, including Redmond.

B. Timing and Duration

Subduction zone earthquakes can happen at any time with shaking likely to last several minutes.[41]

39 Ruth Ludwin, "Earthquake Hazards in Washington and Oregon," The Pacific Northwest Seismic Network, http://www.pnsn.org/INFO_GENERAL/eqhazards.html.
40 Michael A. Fisher et al., "Crustal Structure and Earthquake Hazards of the Subduction Zone in Southwestern British Columbia and Western Washington," U.S. Geological Survey, http://pubs.usgs.gov/pp/pp1661c/pp1661c.pdf.
41 Cascadia Region Earthquake Workgroup; Pacific Northwest Seismic Network Staff, "Earthquake Hazards in Washington and Oregon: Three Sources," The Pacific Northwest Seismic Network, http://www.pnsn.org/CascadiaEQs.pdf.

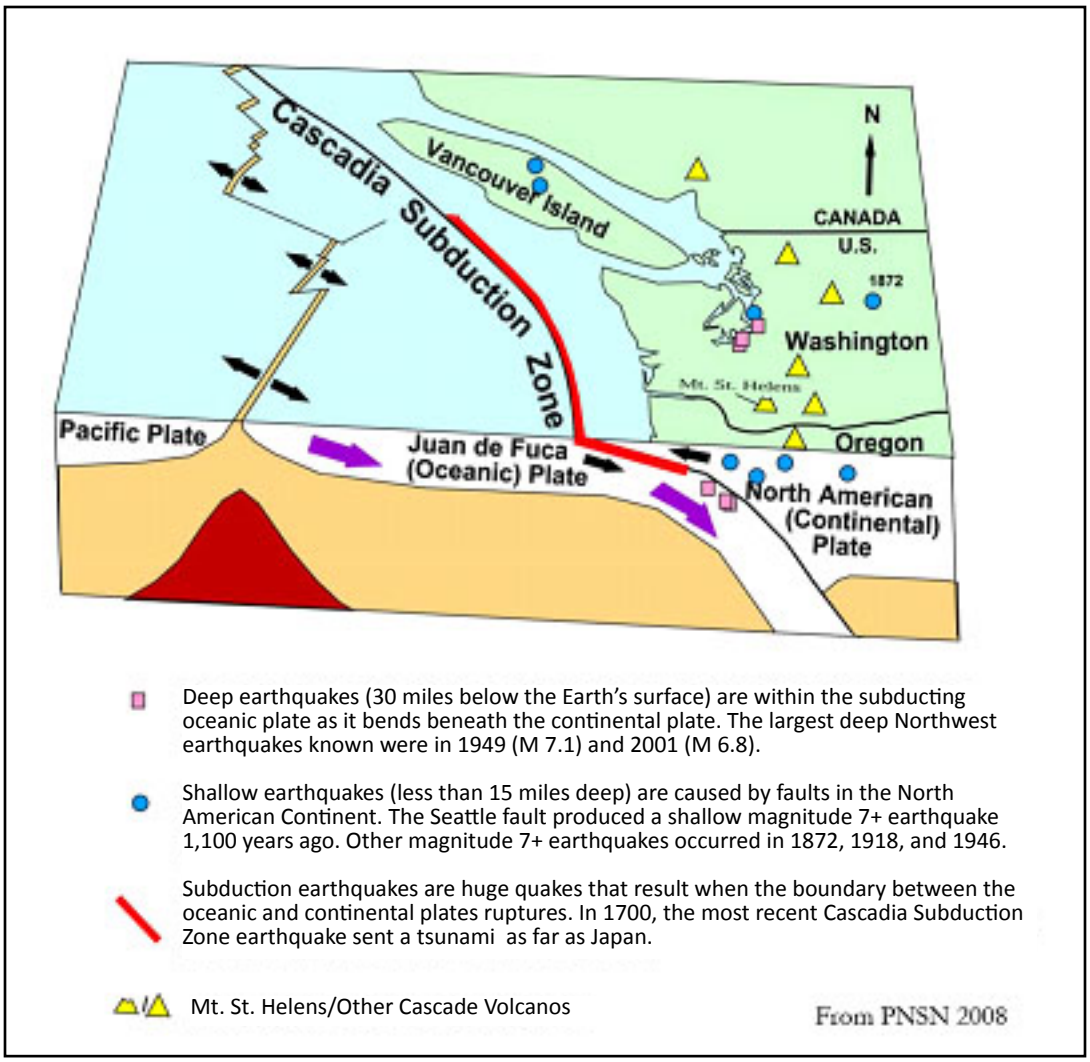


Figure 6: Earthquake Types in Washington
Source: Ruth Ludwin, Earthquake Hazards in Washington and Oregon: Three Source Zones.

C. Severity

Subduction zone earthquakes are extremely powerful, typically registering a magnitude of 8 to 9+ on the Richter scale.[42] However, due to the location of the Juan de Fuca Plate, an earthquake of 8 or 9 magnitude would have a reduced local impact in Redmond. Such an earthquake would have similar shaking to the 2001 Nisqually earthquake (a magnitude 6.8, Benioff earthquake that lasted 2 minutes) but it would last much longer.

Subduction zone earthquakes cause longer shock waves than Benioff quakes and will be felt from a greater distance than the 2001 Nisqually earthquake.[43]

42 Ray Flynn et al., "The Cascadia Subduction Zone – What is it? How big are the quakes? How often?" The Pacific Northwest Seismic Network, http://www.pnsn.org/HAZARDS/CASCADIA/cascadia_zone.html.
43 Cascadia Region Earthquake Workgroup, "Subduction Zone Earthquakes: A Magnitude 9.0 Earthquake Scenario, 2005," http://www.crew.org/papers/CREWCascadiaFinal.pdf.

The Modified Mercalli Scale	Level of Damage	The Richter Scale
1 - 4 Instrumental to Moderate	No damage.	4.3 or Below
5 - Rather Strong	Damage negligible. Small, unstable objects displaced or upset; some dishes and glassware broken.	4.4 - 4.8
6 - Strong	Damage slight. Windows, dishes, glassware broken. Furniture moved or overturned. Weak plaster and masonry cracked.	4.9 - 5.4
7 - Very Strong	Structure damage considerable, particularly to poorly built structures. Chimneys, monuments, towers, elevated tanks may fail. Frame houses moved. Trees damaged. Cracks in wet ground and steep slopes.	5.5 - 6.1
8 - Destructive	Structural damage severe; some will collapse. General damage to foundations. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground; liquefaction.	6.2 - 6.5
9 - Ruinous	Most masonry and frame structures/foundations destroyed. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Sand and mud shifting on beaches and flat land.	6.6 - 6.9
10 - Disastrous	Few or no masonry structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Rails bent. Widespread earth slumps and landslides.	7.0 - 7.3
11 - Very Disastrous	Few or no masonry structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Rails bent. Widespread earth slumps and landslides.	7.4 - 8.1
12 - Catastrophic	Damage nearly total. Large rock masses displaced. Lines of sight and level distorted.	Above 8.1

Table 12: Modified Mercalli Scale and Richter Scale
Source: FEMA for Kids, "The Disaster Area: Intensity Scales," Federal Emergency Management Agency, http://www.fema.gov/kids/intense.htm.

D. Frequency

The last large subduction zone earthquake to hit Washington State occurred on January 26, 1700 and had a magnitude of 9.0.[44] This type of earthquake occurs, on average, every 400 to 600 years.[45]

5.2.2 Benioff (Deep) Earthquakes

A. Location

Benioff (deep) earthquakes in this region typically occur at a depth of approximately 15 to 60 miles below Western Washington. This occurs when the Juan de Fuca Plate slips against the North American Plate. This kind of earthquake would affect all of Redmond and the surrounding region.[46]

44 Ray Flynn et al., "The January, 1700 Cascadia Subduction Zone Earthquake and Tsunami," The Pacific Northwest Seismic Network, http://www.pnsn.org/HAZARDS/CASCADIA/cascadia_event.html.
45 Cascadia Region Earthquake Workgroup; Pacific Northwest Seismic Network Staff, "Earthquake Hazards in Washington and Oregon: Three Sources," The Pacific Northwest Seismic Network, http://www.pnsn.org/CascadiaEQs.pdf.
46 Ruth Ludwin, "Deep Quakes in Washington and Oregon," The Pacific Northwest Seismic Network, http://

B. Timing and Duration

Benioff earthquakes may happen at any time. Shaking will last a minute or less. Aftershocks are less commonly associated with Benioff earthquakes than with other types of earthquakes.[47]

C. Severity

Benioff Zone earthquakes reach magnitudes of 7.5. These deep earthquakes can be high in magnitude, but the depth makes them less violent in terms of lateral acceleration than a similarly sized crustal (shallow) earthquake.

Compared to a subduction zone earthquake, the shaking from a Benioff earthquake will not be felt as far away and the shaking will not last as long. Due to the dip-slip character of Benioff earthquakes, large aftershocks are not common.[48] Benioff (deep) earthquakes are not the most severe of the types of earthquakes that affect Redmond.[49]

D. Frequency

Benioff earthquakes occur most frequently in Redmond. This type of earthquake occurs roughly every 30 years.[50] There have been three major deep earthquakes in recent history: the 7.1 magnitude 1949 Olympia earthquake, the 6.5 magnitude 1965 Seattle-Tacoma earthquake, and the 6.8 magnitude 2001 Nisqually earthquake.[51]

5.2.3 Crustal (Shallow) Earthquakes

A. Location

When the Juan de Fuca plate subducts beneath the North American plate, deformation of the crust causes crustal faults to form. Shallow earthquakes originate less than 15 miles below the surface of the earth.

The Seattle Fault and South Whidbey Fault (see **Map 12, Regional Crustal Faults**) are the two major crustal fault systems that can affect Redmond.[52] The proximity of both of these faults to Redmond increases the potential damage. HAZUS[53] has been run for possible events that have epicenters within close proximity to Redmond.

www.pnsn.org/INFO_GENERAL/platecontours.html.

47 Cascadia Region Earthquake Workgroup; Pacific Northwest Seismic Network Staff, "Earthquake Hazards in Washington and Oregon: Three Sources," The Pacific Northwest Seismic Network, http://www.pnsn.org/CascadiaEQs.pdf.

48 Ruth Ludwin, "Deep Quakes in Washington and Oregon," The Pacific Northwest Seismic Network, http://www.pnsn.org/INFO_GENERAL/platecontours.html.

49 Cascadia Region Earthquake Workgroup, "Subduction Zone Earthquakes: A Magnitude 9.0 Earthquake Scenario, 2005," http://www.crew.org/papers/CREWCascadiaFinal.pdf.

50 Ibid.

51 Ruth Ludwin, "Deep Quakes in Washington and Oregon," The Pacific Northwest Seismic Network, http://www.pnsn.org/INFO_GENERAL/platecontours.html.

52 Michael A. Fisher et al., "Crustal Structure and Earthquake Hazards of the Subduction Zone in Southwestern British Columbia and Western Washington," U.S. Geological Survey, http://pubs.usgs.gov/pp/pp1661c/pp1661c.pdf.

53 HAZUS is FEMA's Methodology for Estimating Potential Losses from Disasters. HAZUS is a powerful risk assessment methodology for analyzing potential losses from floods, hurricane winds and earthquakes. In HAZUS, current scientific and engineering knowledge is coupled with the latest geographic information systems (GIS) technology to produce estimates of hazard-related damage before, or after, a disaster occurs. http://www.fema.gov/plan/prevent/hazus/.

B. Timing and Duration

Crustal earthquakes can happen at any time with shaking that lasts approximately 30 seconds. Crustal quakes have the shortest duration of the three types of earthquakes.[54]

C. Severity

Of the three types of earthquakes, crustal earthquakes are currently thought to present the greatest risk to the Puget Sound region.[55] While they tend not to last as long as the other types of earthquakes, the short shock waves associated with them cause more violent ground shaking for the entire region than the other types of earthquakes.[56]

D. Frequency

The largest known crustal earthquakes in the Puget Sound region took place in the years 900 and 1872. Each had magnitudes of approximately 7.4 on the Richter scale.[57] Recurrence intervals are unknown.

5.3 Assessing Earthquake Vulnerability

5.3.1 Overview

Redmond's vulnerability to an earthquake is based on a variety of factors including its proximity to subduction zones and faults. Vulnerability of the built environment depends on the location, age, material, and condition of manmade structures. The natural environment's vulnerability reflects the existing condition and the characteristics of the event. The City's dependence on regional systems, the density of the population, and available resources impact Redmond's overall vulnerability to an earthquake.

The potential for severe earthquakes makes Redmond very vulnerable to the impacts. While the most intense damage will likely be confined to the liquefaction zone, the whole city and surrounding region will be affected at least marginally.

5.3.2 Profiling the Vulnerabilities

A. Man-made

Table 13: Effect of Earthquakes on Different Types of Buildings represents how each of the different types of earthquakes will affect man-made structures.

54 Cascadia Region Earthquake Workgroup, "Subduction Zone Earthquakes: A Magnitude 9.0 Earthquake Scenario, 2005," http://www.crew.org/papers/CREWCascadiaFinal.pdf.
55 Ruth Ludwin, "Earthquake Hazards in Washington and Oregon," The Pacific Northwest Seismic Network, http://www.pnsn.org/INFO_GENERAL/eqhazards.html.
56 Cascadia Region Earthquake Workgroup; Pacific Northwest Seismic Network Staff, "Earthquake Hazards in Washington and Oregon: Three Sources," The Pacific Northwest Seismic Network, http://www.pnsn.org/CascadiaEQs.pdf.
57 Ruth Ludwin, "Shallow Crustal Quakes in Washington and Oregon," The Pacific Northwest Seismic Network, http://www.pnsn.org/HAZARDS/SHALLOW/welcome.html.

Earthquake Type	Skyscrapers	Mid-rise Structures	Wood Structures (under 5 stories)
Subduction Zone	May have structural damage or total collapse.	May have structural damage, but not as much as skyscrapers.	May have structural damage, but not as much as skyscrapers.
Benioff (Deep)	Structural damage is unlikely.	May have structural damage.	May have structural damage, but not as much as mid-rise structures.
Crustal (Shallow)	Structural damage is unlikely.	May have structural damage, but not as much as short, wood structures.	May have structural damage.

Table 13: Effect of Earthquakes on Different Types of Buildings

Developed areas in the soil liquefaction zone are particularly vulnerable to damage and structural failure. In any earthquake, older buildings or buildings that do not meet current codes are more vulnerable.

Approximately 7.5% of residential buildings (or 990 of the 13,386 residential buildings) and almost 49% of commercial and public buildings (or 1,968 of the 4,022 non-residential buildings) in Redmond are located in the low to high liquefaction areas (see **Map 15, City of Redmond Buildings Vulnerable to Soil Liquefaction**).

Developed areas are also vulnerable to secondary hazards of earthquakes such as landslides and fires. See corresponding hazards for specific information regarding vulnerability to secondary hazards.

B. Natural

The vulnerability to the natural environment primarily stems from secondary hazards such as liquefaction or other soil failure, landslides, seiche, fires, and hazardous materials spills. See information regarding specific hazard vulnerabilities for fires, landslides and hazardous materials spills in their appropriate sections.

C. Systems

The systems in Redmond are extremely vulnerable to an earthquake. Sewers, water pipes, culverts, electrical lines, roads and bridges may be severely damaged or fail during an earthquake.

An earthquake will cause a great deal of damage to the transportation systems in Redmond. The roads may be covered by debris or be affected by secondary hazards such as landslides or fires. The bridges are particularly vulnerable to collapse. Damage or collapse of the bridges over the Sammamish River or Bear Creek would isolate the Education Hill neighborhood. Damage or a collapse along SR 520 will isolate the entire City of Redmond.

Since there are no hospitals in Redmond and a large portion of first responders do not live within the city, medican and emergency response systems are vulnerable

to failures in the transportation system. If Redmond is cut off from other cities in the region, emergency responders will have difficulty getting to Redmond. During a regional event, hospitals are likely to be overwhelmed. If transportation networks fail, patients from Redmond may not have access to those facilities.

Goods and services may be limited, contributing to the vulnerability of businesses during an earthquake. Transportation failures and general chaos following an earthquake will complicate normal business operations. Consequently, isolated residents may have minimal access to goods and services that are usually provided by local businesses. Should businesses still be operable after an earthquake, the decrease in economic activity (from both suppliers and consumers) stemming from local or regional isolation may force some businesses to experience financial hardship.

Sanitation and water supply systems are vulnerable to damage or collapse from an earthquake, particularly if they are located in the liquefaction zones. Communication systems may be compromised as a result of downed electric and telephone lines, damage to cell phone towers, or overuse of the system immediately following an event. Compromised communication systems will make it difficult for people to report damage or call for assistance.

D. Populations

The impact of an event will affect different populations in different ways depending on capabilities of the population, available resources, and localized impacts.

Hazard Specific

People inside or near buildings that suffer structural damage during an earthquake may become injured or trapped. People in areas of higher density are more vulnerable to falling debris due to lack of open spaces to escape unsafe structures. People who live in liquefaction zones are more likely to be in need of emergency shelter after an event. Water supply infrastructure is extremely vulnerable to damage during an earthquake, particularly the City wells that are located in a liquefaction zone. All residents living east of Sammammish River and Lake, who rely on well water, are more vulnerable to a subsequent hazardous materials spill or sewer breakage because the water supply may become contaminated (see **Map 20, City of Redmond Water Supply and Sewer Infrastructure**).

Isolated Populations

Road blockage or damage may cause local neighborhoods to become isolated. Isolation will decrease the availability of emergency services and access to vital necessities like food and water. Residents in Education Hill, Overlake and Downtown may be isolated in the days following a major earthquake.

In the event of a major regional earthquake, the entire City may become isolated from the rest of the Puget Sound Region. According to the Washington State Department of Transportation (WSDOT), the floating bridge on SR 520 will likely collapse in the

event of a major earthquake.[58] People in Redmond may be isolated due to the large number of City employees that reside outside the City and the lack of resources, supplies, and increased difficulty to reach medical facilities.

Disabled Persons
Disabled persons are more vulnerable in an earthquake than people who are not disabled because they cannot respond to the event as quickly. Moving out of the way of falling debris or navigating obstacles may be more difficult for a disabled person. This may hinder their ability to get to a safe area or get help.

Children
An earthquake during school hours may separate children from their families. Children may have limited transportation options when attempting to reunite with their parents.

Elderly
Decreased agility makes elderly people more vulnerable to an earthquake. Elderly with compromised immune systems or other health needs may experience delayed emergency services or limited access to prescriptions. People with limited mobility or transportation options are more likely to become isolated in their homes. Those that rely on electrically powered medical devices are particularly vulnerable to power outages.

Limited English Language
Language barriers may inhibit individuals from getting help from emergency services or limit their access to critical information. During work and school hours, it is more likely that people with limited proficiency will be isolated.

Low-income Residents
People with limited financial resources may not be able to pay for immediate emergency services. Should employment centers close as a result of an earthquake, these unexpected days without work may impose a significant financial hardship. Costly mitigation and preparation strategies, like attaching homes to their foundations, may also be difficult for low-income residents. Limited mitigation and insufficient emergency funds make low-income residents vulnerable.

5.3.3 Analyzing Development Trends

Currently, approximately 7.5% of residential buildings and almost 49% of non-residential buildings (commercial and public) in Redmond are located in the liquefaction zone. The City's Future Land Use Map (FLUM) indicates there will be increased density in Downtown. Much of the liquefaction area is zoned for mixed use that will include various combinations of multi-family housing, single-family homes, businesses, manufacturing, urban recreation, parks and open space. For information

58 "WSDOT Projects: SR 520 Program - Safety and Vulnerability." http://www.wsdot.wa.gov/Projects/SR520Bridge/vulnerability.htm

on how development trends are pertinent to secondary hazards, such as landslides and fires, refer to the corresponding sections.

5.4 Scenarios

A. Subduction Zone Earthquake

On September 5th, at 11:35 a.m., a large subduction zone earthquake shook the whole Puget Sound region for nearly ten minutes. It reached 8.1 on the Richter Scale. A metal gas line broke during the earthquake and sparked a fire at the north edge of the City. Since it has not rained in three weeks, four fires began in the immediate aftermath of the earthquake. Due to regional destruction, the Redmond Fire Department is unable to get additional assistance from neighboring communities.

Several high-rise buildings in Seattle and Bellevue completely collapsed in the earthquake. Two days after the shaking, emergency responders are still working to rescue people from the rubble. There are ten reported deaths and over thirty people remain missing.

Most of Redmond's mid-rise and wood-frame buildings are still intact, although there was some damage to the buildings in the downtown area that have brick and stone facades. Some older homes with brick chimneys also experienced damage. Due to transportation network failures, schools remained open until 8 p.m. until all children could be reunited with their families. SR 520 was closed for thirty-six hours until all overpasses were determined to be safe.

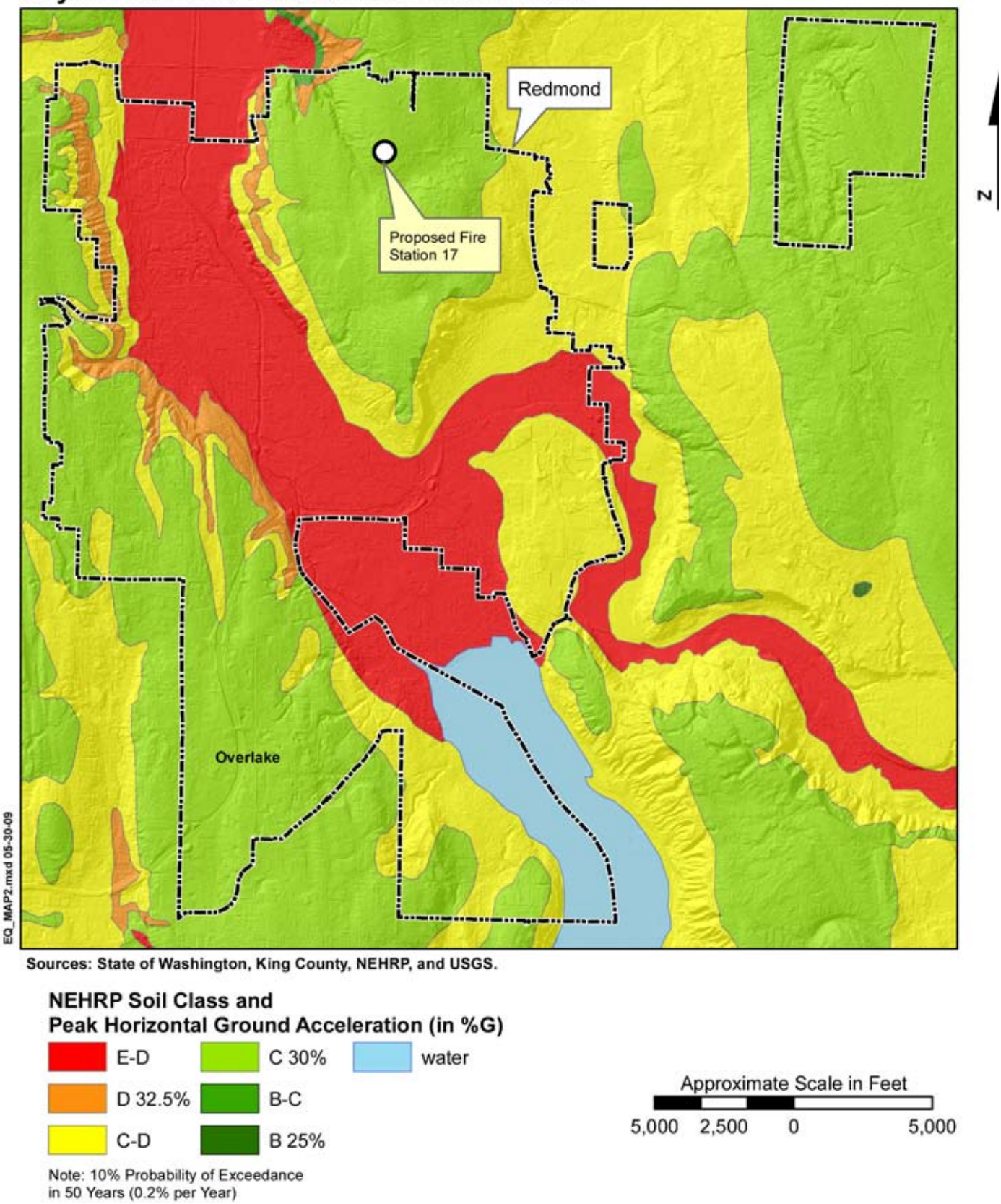
B. Benioff (Deep) Earthquake

On April 15th, at 9:20 a.m., a deep, Benioff earthquake shook the ground for one and a half minutes. In Redmond, there was some soil liquefaction, but it has been minimal and similar to effects from the 2001 Nisqually earthquake. There is little damage to the structures in the City, most of which affect the older downtown buildings with unreinforced masonry. The falling debris downtown injured two people, no deaths were reported. It rained for five days before the earthquake, the ground was fairly saturated. No major landslides have occured, but some people have noticed some slight shifting on some hillsides. Most of the region has not experienced very much damage thus far, so connections remain stable and Redmond remains resilient.

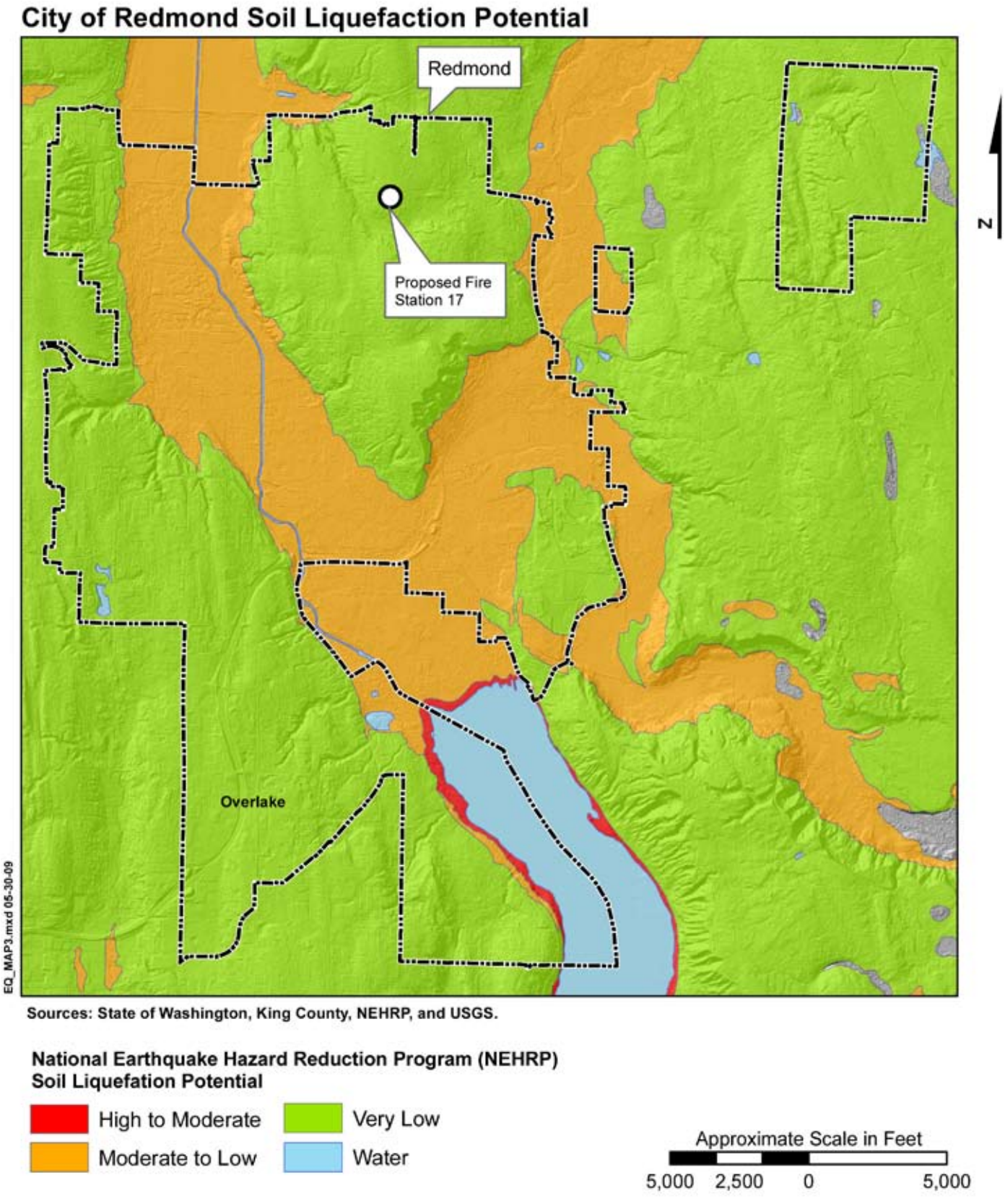
C. Crustal (shallow) Earthquake

See Part 3, Scenario 1. Appendix C shows the global report from HAZUS for a 6.7 magnitude earthquake on the Seattle Fault.

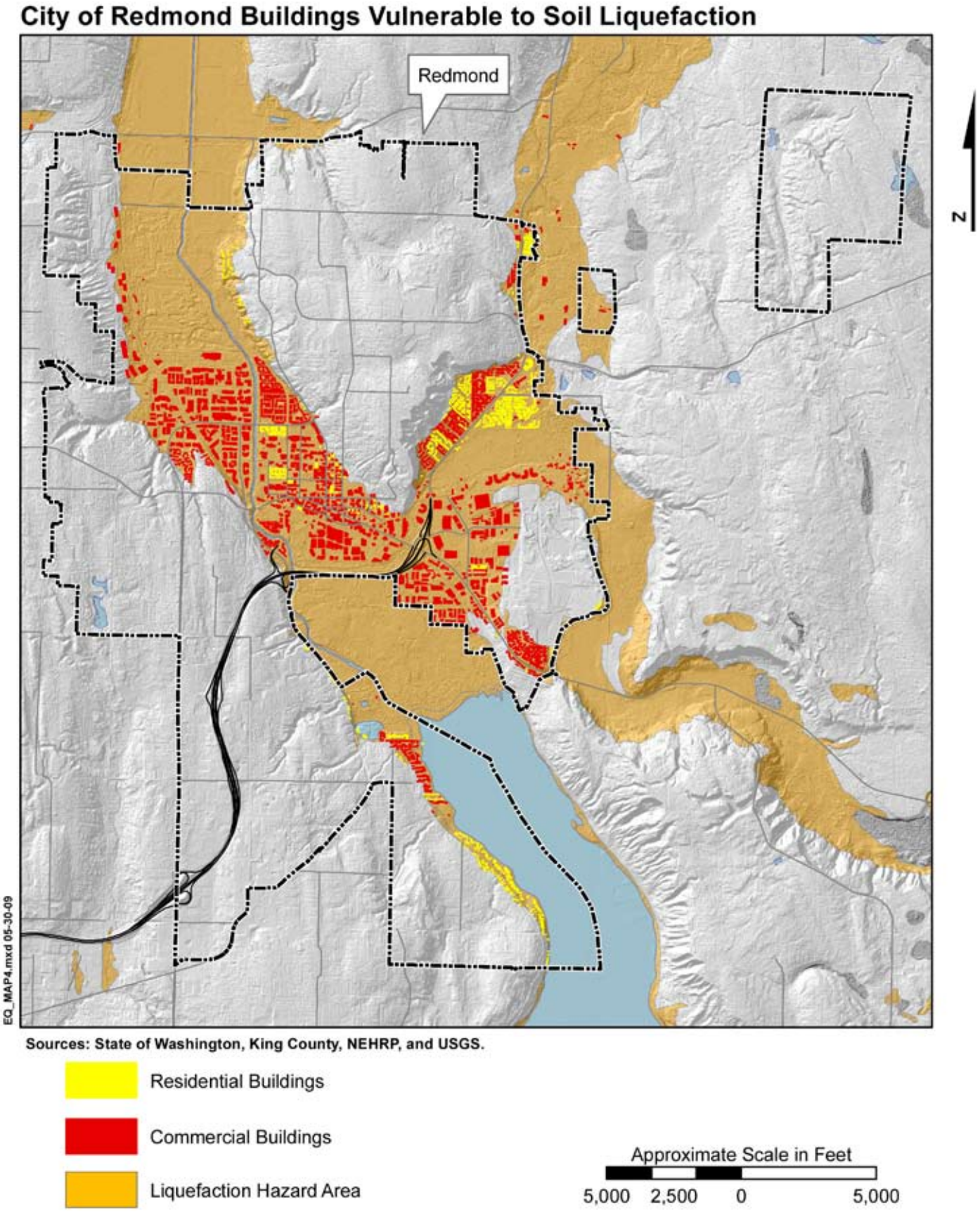
City of Redmond Probabilistic Seismic Risk



Map 13: City of Redmond Probabilistic Seismic Risk



Map 14: City of Redmond Soil Liquefaction Hazard



Map 15: City of Redmond Soil Liquefaction Vulnerability

Floods Risk Assessment

This plan is an update of the 2004 City of Redmond Hazard Mitigation Plan (HMP). Although it is an update, this document has been redesigned so that it looks, feels, and reads differently than the original. This is due to several factors: new hazard information has become available that drives new definitions of risk, the City has matured and new capabilities are now available, and the new format will allow readers to more easily understand the content. In addition, the 2004 HMP included several action items that have been completed, creating an opportunity for developing new mitigation strategies.

6.1 Identify Flood Hazards

A flood is a temporary inundation with water of normally dry land[59]. Flooding can be caused by a body of water such as a river overflowing its banks or by a rapid accumulation of surface-water runoff.[60] Built structures can become flooded by groundwater seepage when the water table rises or the surrounding ground becomes saturated.

Flood damage can range from minimal localized damage to complete destruction of built structures. The velocity and volume of water present a risk in a flood event. Additionally, contaminants in the water pose a secondary threat.[61] Flood water may contain gasoline or other hazardous chemicals as well as debris. Consequently, flooding can present both immediate concerns and secondary effects.

FEMA requires municipalities to plan for the 100-year flood. The 100-year floodplain is an area that has a 1% chance of flooding in any given year.[62]

Climate Change Impact

Research conducted by the International Panel on Climate Change suggests that within any given future year, wetter winters with increasing rainfall and rain intensity can be expected.[63] In Redmond, this will lead to a higher frequency of flood events as well as the potential raising of the water level. Anticipated climate changes suggest that Redmond will experience more flooding from groundwater seepage and more frequent flooding along the Bear Creek and Sammamish River trails and Lake Sammamish.

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59 Janet Thingpen, *Stream Processes*: *A Guide to Living in Harmony with Streams* (New York: Chemung County Soil and Water Conservation District, 2006), 68.
60 National Flood Insurance Program, "Flooding and Risks: What Causes Flooding," Federal Emergency Management Agency, http://www.floodsmart.gov/floodsmart/pages/flooding_flood_risk/what_causes_flooding.jsp.
61 Federal Emergency Management Agency and American Red Cross, *Repairing Your Flooded Home*, (Washington DC: FEMA Publications, 1992), 15.
62 Susan Bolton, JL Clark, Bob Freitag, and Frank Westurland, *Getting Wet: Benefiting from Flooding in the 21st Century*, (Draft, 2009), 9.
63 Climate Impacts Group: Joint Institute for the Study of the Atmosphere and Ocean, "Seasonal to Interannual Forecasts; Extreme Weather: Background," University of Washington, http://cses.washington.edu/cig/fpt/exbackground.shtml.

6.2 Profiling Flood Hazard Events

A. Location

The Sammamish River, Bear Creek, Evans Creek, and parts of Lake Sammamish are located within the City limits of Redmond. A large portion of Redmond's downtown district lies within the 100-year Sammamish River floodplain. **Map 16, City of Redmond 100-Year Floodplain and Chronically Flooded Areas**, shows the location of the floodplain and the waterways. Swelling or over-topping of the Lake Sammamish will flood lakeside homes and docks. The high water table, with an estimated average depth of 25 feet, increases the likelihood of seepage flooding.

Areas regularly flooded include parts of the Sammamish River and Bear Creek trail systems, portions of the City's Municipal Campus, condominium developments along Lake Sammamish, and an area near Bear Creek's Friendly Village Mobile Home Park. **Map 16, City of Redmond 100-Year Floodplain and Chronically Flooded Areas,** illustrates areas of chronic flooding in Redmond and identifies flood-related capital improvement projects (CIPs).

The majority of structural flooding in Redmond occurs in buildings with crawl spaces, basements, subsurface parking or other underground development. The swelling of the Sammamish River causes the water table to rise, which then seeps into underground spaces. In January 2009, the Lake Sammamish condominium owners and the Friendly Village mobile home owners used sandbags to block water from entering their structures.

The City of Redmond is a member of the National Flood Insurance Program. Residents living in the 100-year floodplain are required to have flood insurance. There have only been five claims within Redmond's City limits through FEMA's National Flood Insurance Program (NFIP). The locations of the claims are shown in **Map 17, City of Redmond NFIP Claims and Holders**. Only one of the five claims lies within the 100-year floodplain. The remaining claims were the result of groundwater seepage or drainage problems.

B. Timing and Duration

Weather forecasts and the close monitoring of local water systems normally provide substantial warning prior to flooding. 50% of Redmond's annual precipitation typically occurs in the four-month period from October through January and 75% occurs in the six-month period from October through March.[64] Flash floods or floods caused by a collapse of land along a shoreline have a significantly shorter warning time.

Groundwater seepage and stormwater runoff cause most of the flooding in Redmond. Since the wet season is the typical time for these issues, the City usually has adequate time to prepare. Also, much of the City is far enough away from the Sammamish

64 King County Department of Natural Resources and Parks, Water and Land Resources Division, "2006 King County Flood Hazard Management Plan," King County River and Floodplain Management Program.

River that groundwater level may take up to six hours[65] to rise in response to a Sammamish River flood event. Knowledge gained from past occurrences can also help localized areas of flooding prepare for future events.

The duration of a flooding event may be limited to a few hours or may extend for several days or even weeks.

C. Severity

Though frequent, flood events in Redmond are not particularly severe. According to the FEMA 100-year flood depth grids, the majority of the floodplain will become inundated by only one foot of water. Two small portions of the floodplain near the convergence of Bear Creek and the Sammamish River are susceptible to inundation between two and three feet (see **Map 18, City of Redmond Buildings Vulnerable to Flooding**). Since the 100-year floodplain is large, deep floodwaters are not a concern. Flood damage costs in Redmond are typically low compared to other King County municipalities.

Although flooding in Redmond tends to be shallow, water on roadways may cause significant road damage and limit access to important transportation routes or other services. While it is important to note that Redmond is not susceptible to large-scale severe flooding, any amount of water on a roadway in Redmond will create significant problems for the City, its residents, and those that are employed within its boundaries.

Redmond's building codes are based on a 100-year Sammamish River flood with a flow rate of 1,920 CFS (cubic feet per second). The resulting codes are stricter than the FEMA requirement, which is based on a 100-year Sammamish River flood flow rate of 1,535 CFS.[66] The building codes, in coordination with a well-monitored permitting process, regulate construction in the floodplain. Homeowners with frequently flooded crawl spaces or basements are prepared with water pumps to reduce water damages to their homes.

Should stormwater drains become clogged and overflow into a permeable surface area (such as low impact development practices like permeable pavement, rain gardens, or infiltration trenches; or lawns and other landscaped areas), there is risk of groundwater contamination. Within the City's drinking water wellhead protection zones, this risk has the potential consequence of requiring a very expensive cleanup or loss of up to 40% of the City's drinking water resource. The presence of hazardous materials within flooded areas increases the potential risk to the groundwater during flood events.

D. Frequency

Past Occurrences

In Redmond, the areas along the Bear Creek and Sammamish River trails flood more

65 Bob Franklin, City of Redmond Floodplain Manager, informational interview, April 16, 2009.
66 Bob Franklin, City of Redmond Floodplain Manager, informational interview, April 16, 2009.

frequently than other areas of the City. The United States Army Corps of Engineers' flood control project in the 1960s altered the natural path of Bear Creek and the Sammamish River to reduce flood frequency and severity in Redmond. In recent years, the City has experienced minor flooding almost annually. While such flooding may occur once or twice a winter season, groundwater seepage and stormwater drainage can be a consistent problem in rainy months. **Table 14, Past Occurrences of Flooding in Redmond,** provides specific information about the location and extent of historical flooding.

Past Occurrences of Flooding in Redmond			
Date	**Location**	**Type**	**Extent**
1/18/1986	Bear Creek	Riverine	Roadways over-topped, mobile home park flooded and evacuated
1/3/1997	Sammamish River	Riverine	Over-topping of pedestrian trail near NE 124th St.
1/2006	Bear Creek	Riverine	Reached capacity but did not over-top. Debris collected at bridges that crossed the creek's span.
12/2007	Sammamish River	Riverine	Over-bank inundation of river near NE 85th St, drainage system and storm water flooding at 150th Ave NE and in Overlake area
Chronic	Education Hill	Drainage	Localized flooding of small neighborhood
Chronic	82nd St between 169th Ave NE and 170th Ave NE	Drainage	Roadways within 1-block radius inundated
Chronic	Union Hil Rd. between 185th Ave NE and 196th Ave NE	Drainage	Nuisance flooding of existing street and parking areas of local businesses
Chronic	NE 40th St and Bel-Red road	Drainage	Localized nuisance flooding in intersection
Chronic	3060 and 3068 W Lk Sammamish Pkwy	Drainage	Nuisance ponding
Chronic	4850 162nd Ave NE, Marymoor Hills	Drainage and Seepage	Localized flooding; flooding of crawlspaces
Chronic	Willows Business Park 152nd	Drainage	Frequent nuisance flooding
Chronic	8350 164th Ave NE, 8450 165th Ave	Drainage	Frequent flooding of parking lot
Chronic	Willows Business Park 92nd St	Stream/Riverine/ Drainage	Nuisance flooding
Chronic	14001 NE 72nd St	Drainage	Localized flooding
Chronic	15000 NE 95th St	Drainage	Frequent nuisance flooding of parking lots
Chronic	156th Ave NE and NE 56th Way	Drainage	Ponding, Damage to paved surfaces
Chronic	162nd Ave NE and NE 57th St	Drainage	Ponding, Damage to paved surfaces
Chronic	140th Ave and NE 70th St	Drainage	Ponding, Damage to paved surfaces
Chronic	156th Ave NE and NE 65th Way	Drainage	Ponding, Damage to paved surfaces
Chronic	NW corner of Marymoor Park, South of 18000 NE 65th St	Drainage	Blocked access to loading docks and building entrances

(Table 14 continued on next page)

Past Occurrences of Flooding in Redmond (continued)			
Date	**Location**	**Type**	**Extent**
Chronic	2812 183rd Ave NE	Seepage	Groundwater flows year-round across sidewalk
Chronic	NE 48th St Conveyance	Drainage and Seepage	Capacity issues with groundwater under roadway
Chronic	Willows View Apartments	Drainage and Seepage	Water on sidewalks; damaged rockery
Chronic	17750 NE 21st St	Drainage	Damaged rockery
Chronic	176th Ave NE and NE 70th St	Drainage	Ponding, water over roadway
Chronic	S side of NE 24th, west of 179th Ave NE	Drainage	Blockage of culverts
Chronic	2000 West Lake Sammamish Pkwy	Drainage	Ponding on roadway
Chronic	9216 162nd Pl NE	Drainage	Flooding behind residential home
Chronic	Eastside of 146th just south of Old Redmond Rd	Drainage	Flooding of street; in 1993 flooding of homes
Chronic	177th Ave NE; Argyle Division	Drainage and Seepage	Surface erosion and flooding from pipe seepage
Chronic	City of Redmond Public Safety Building	Seepage	Flooding of below-ground parking garage
Chronic	Marriot Hotel	Seepage	Flooding of below-ground parking garage
Chronic	Sammamish River Trail and Bear Creek Trail	Riverine	Inundation of paved pedestrian trails making them impassable.

Table 14: Past Occurrences of Flooding in Redmond
Sources: City of Redmond Department of Natural Resources, "Stormwater Capital Improvement Program and City of Redmond," City of Redmond, http://www.redmond.gov/insidecityhall/publicworks/stormwater/cipstormwater.asp and City of Redmond Department of Natural Resources, "2009 Comprehensive Flood Hazard Management Plan".

Probability of Future Events

With climate change, more development in the watershed, increased stormwater runoff, and the introduction of more impermeable surfaces, the frequency of localized flooding events is likely to increase. Climate change research suggests an increase of extreme weather patterns with wetter winters characterized by increased precipitation and intensity.[67] The projected changes will increase the occurrence and severity of flooding events in Redmond.

6.3 Assessing Flood Vulnerabilities

6.3.1 Overview

Three large bodies of water coupled with a high water table pose a risk of flooding in Redmond. The presence of valuable buildings, infrastructure, natural environment and people make the City vulnerable to riverine and seepage flooding. Irregular weather and precipitation patterns resulting from climate change will also increase the City's vulnerability to floods.

67 Climate Impacts Group: Joint Institute for the Study of the Atmosphere and Ocean, "Seasonal to Interannual Forecasts; Extreme Weather: Background," University of Washington, http://cses.washington.edu/cig/fpt/exbackground.shtml.

6.3.2 Profiling the Vulnerabilities

A. Man-made

Though riverine floods have been relatively mild in Redmond, flooding does cause damage to the built environment. **Map 18, City of Redmond Buildings Vulnerable to Flooding,** shows the flood depths and buildings located within the 100-year floodplain. There are 166 buildings located within the 100-year floodplain. Of these, 116 are single-family and 50 are multi-family units.[68] The mean appraised value of the buildings is $2.1 million.[69] The City of Redmond does not have any repetitive loss structures.

Map 17, City of Redmond NFIP Claims and Holders, shows the buildings in the floodplain, NFIP holders and properties that have filed flood insurance claims. The claims range from $0 to $11,199 and average approximately $2,600. Four of the five flood insurance claims have been related to seepage flooding outside of the floodplain.

Lakeside homes and docks are vulnerable to swelling or overtopping of the lake. As shown in **Map 18, City of Redmond Buildings Vulnerable to Flooding**, there are many lakeside homes within the floodplain.

B. Natural

The most significant threat posed by floods to the natural environment is the potential damage to fish and wildlife habitat. Channel alteration may affect wetlands and habitats in frequently flooded areas. A 25 to 50-year flood event in Bear Creek may result in significant damages to delicate riparian vegetation. The runoff associated with development and increased impervious surfaces has increased the occurrence of flooding. Runoff, bank erosion, sedimentation and siltation can alter the aquatic ecosystem and be potentially devastating to the fish habitat. While building in a floodplain may damage ecosystems, a flood induced by encroachment on the floodplain may further this damage by introducing toxins, debris, and significant amounts of sediment to the system. The flood's flow velocity may further increase losses to the ecosystem by removing riparian vegetation and salmon spawning areas.

Critical areas likely to be affected by flooding, including fish and wildlife habitat and wetlands, are shown in **Map 19, City of Redmond Natural Environment Vulnerable to Flooding**. Although these areas experience natural flooding, further development and climate change impacts may cause regular flooding events to have a greater impact on the natural environment. In addition to the Endangered Species Act's (ESA) designation of the Puget Sound Chinook salmon and bull trout as endangered species, Redmond is working hard to restore habitat in and near streams that will benefit species that have been listed, and other species, too.

68 City of Redmond Department of GIS Services. 1999. RedmondGIS.DBO. Building GIS data layer.
69 King County. Department of Assessments. Real Property Account. Assessorshttp://www.metrokc.gov/Assessor/download/download.asp

C. Systems

Transportation, water systems, sewer systems and businesses located in the 100-year floodplain are vulnerable to flooding.

Sewer, stormwater and underground well water infrastructure are vulnerable to both riverine and stormwater and seepage floods. Since 40% of Redmond's water supply is provided by public wells, contamination of the wells would limit the availability of clean, fresh water in the City. Contamination of the groundwater would be difficult, if not impossible, to reverse. **Map 20, City of Redmond Water Supply and Sewer Infrastructure**, shows the location of sewer and water facilities that are located in the floodplain and critical areas.

Though rare, severe riverine flooding may shut down arterial parts of transportation systems. This could isolate neighborhoods or the entire City of Redmond. **Map 21, City of Redmond Vulnerable Transportation Networks**, shows transportation routes crossing the 100-year floodplain.

Transportation closures may limit businesses' abilities to operate normally. Businesses may be forced to close temporarily due to lack of patronage and/or employee absences. The disruption of delivery would also have negative impacts on the local economy. Small businesses are particularly vulnerable to temporary closures and property damage.

D. Populations

Hazard Specific

People with property located in the floodplain or within areas subject to seepage are vulnerable to flooding.

Isolated Populations

Transportation and road closures could isolate some neighborhoods. Due to the separation from downtown and major routes to the surrounding region, Education Hill may become isolated during an extreme flooding event. Services and supplies may be limited in the event of a flood.

Children

Flooding that occurs when children are separated from their families may result in limited resources and access to adequate transportation. Additionally, children may not know the proper precautions to take in the event of a flood.

Elderly

The elderly often have special medical or service needs that make isolation and road closures more serious problems for them compared to other vulnerable populations. **Map 22, City of Redmond Vulnerable Population Housing,** shows the location of retirement homes and senior housing. Three are located within or very near the floodplain. Two are located in the Northeast, which may become isolated.

Limited English Speakers
Residents with limited English proficiency may not have immediate access to emergency announcements, unless translation is provided. Additionally, language barriers may limit access to mitigation opportunities and opportunities to provide input in the Comprehensive Flood Hazard Management Plan. **Map 23, City of Redmond Limited English Language Capability in Floodplain,** shows the areas of limited English speakers.

Low-income Residents
Lack of adequate financial resources increases the vulnerability of low-income residents. This population may not be able to participate in costly mitigation efforts. Renters and mobile home owners may be limited to owner-initiated mitigation efforts. There is only one designated affordable housing[70] building within the floodplain. **Map 22, City of Redmond Vulnerable Population Housing**, shows the location of affordable housing relative to the floodplain. Households with limited income may face an additional hardship responding to flood damages or income losses.

6.3.3 Analyzing Development Trends

The City's Planning Department is currently focusing on an economic development plan to promote and advertise the existing businesses in the downtown area.[71] One of the City's main goals in its Comprehensive Plan is to support vibrant concentrations of retail, office, service, residential, and recreational activity in the Downtown and Overlake neighborhoods. However, additional development in the floodplain will increase the City's vulnerabilities to flooding. While centralized, compact development will provide additional local services, dense development in the floodplain will change the impacts of flooding. Increasing the number of people and structures in the floodplain will increase the potential damages. Additionally, development will decrease permeability and thus increase runoff and the corresponding impacts.

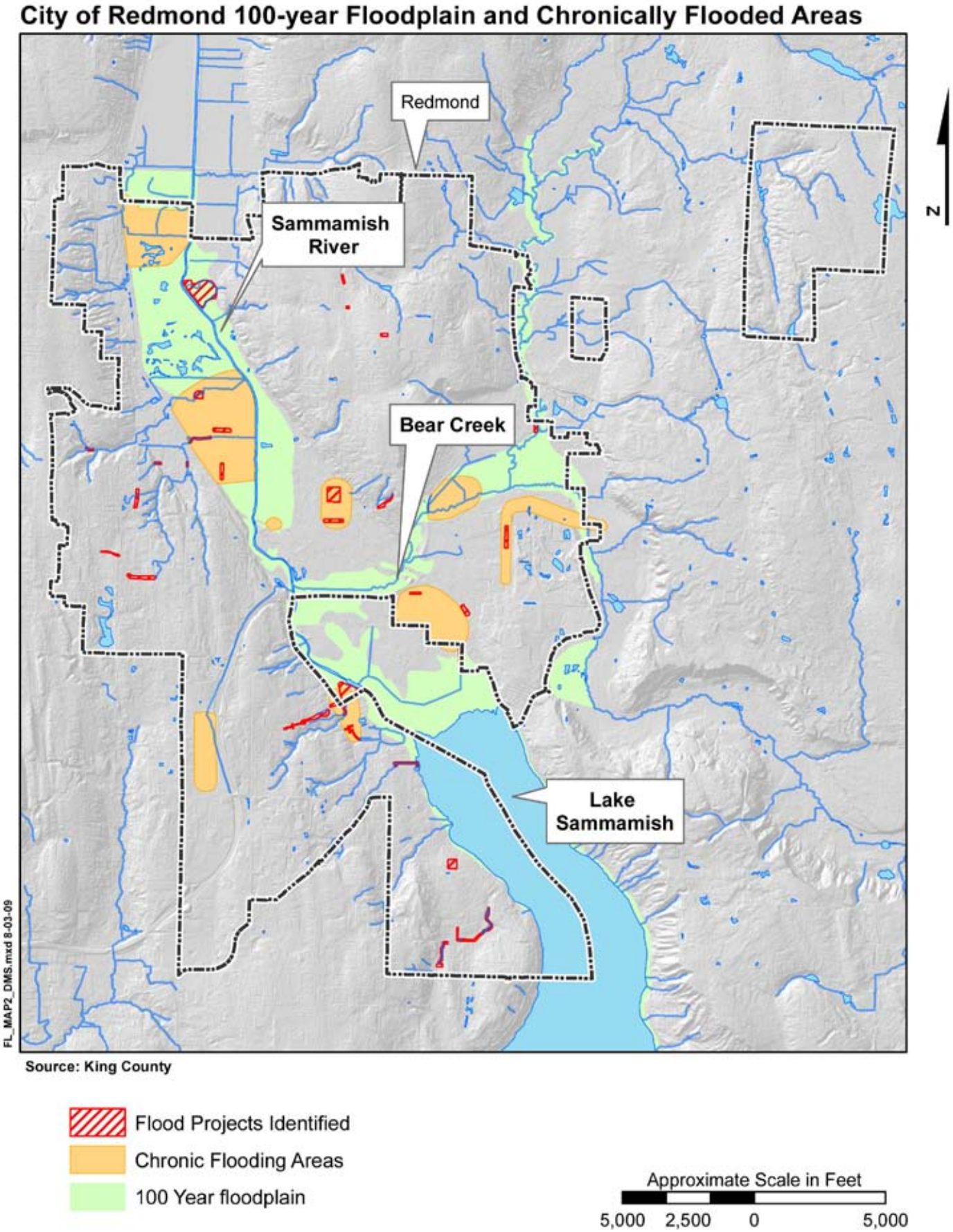
6.4 Scenario

After three consistent days of rain, several reports of backed-up storm drains throughout the city are called in at 3 p.m. Thursday, April 10th. By that evening, ponding of one to two feet deep has occurred throughout the Sammammish valley. Saturated soils haved slowed drainage and caused addtional localized flooding from seepage. Twelve homes and three businesses in the floodplain have reported damage from the floodwaters. Three homes outside the floodplain have reported groundwater seepage in crawlspaces.

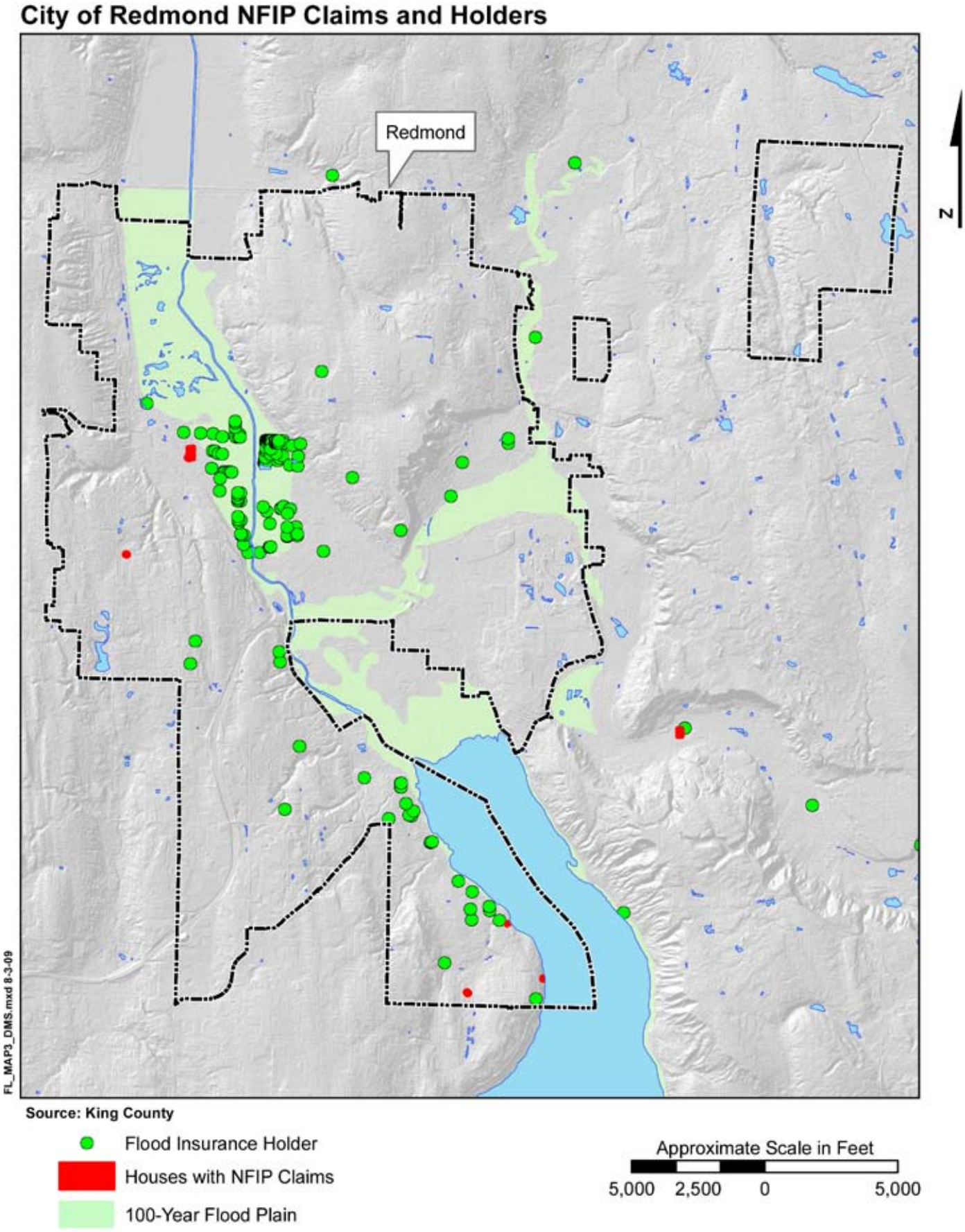
Although lakeside homes are cautious of flooding, landslides pose a greater threat. The saturated banks of Lake Sammamish are showing signs of movement and two homes have been evacuated.

70 Buildings that have income restrictions are the only "affordable housing" units considered in this report. Information is limited for market-rate affordable housing.
71 Jim Roberts, City of Redmond Planning Department, informational interview, 2009.

Roads are extremely wet and flooding on West Lake Sammamish Parkway is limiting traffic to one lane. Businesses are operating on a limited basis due to the difficulty of traversing the valley. Several companies have encouraged employees to work from home. Weather reports predict continued rain.

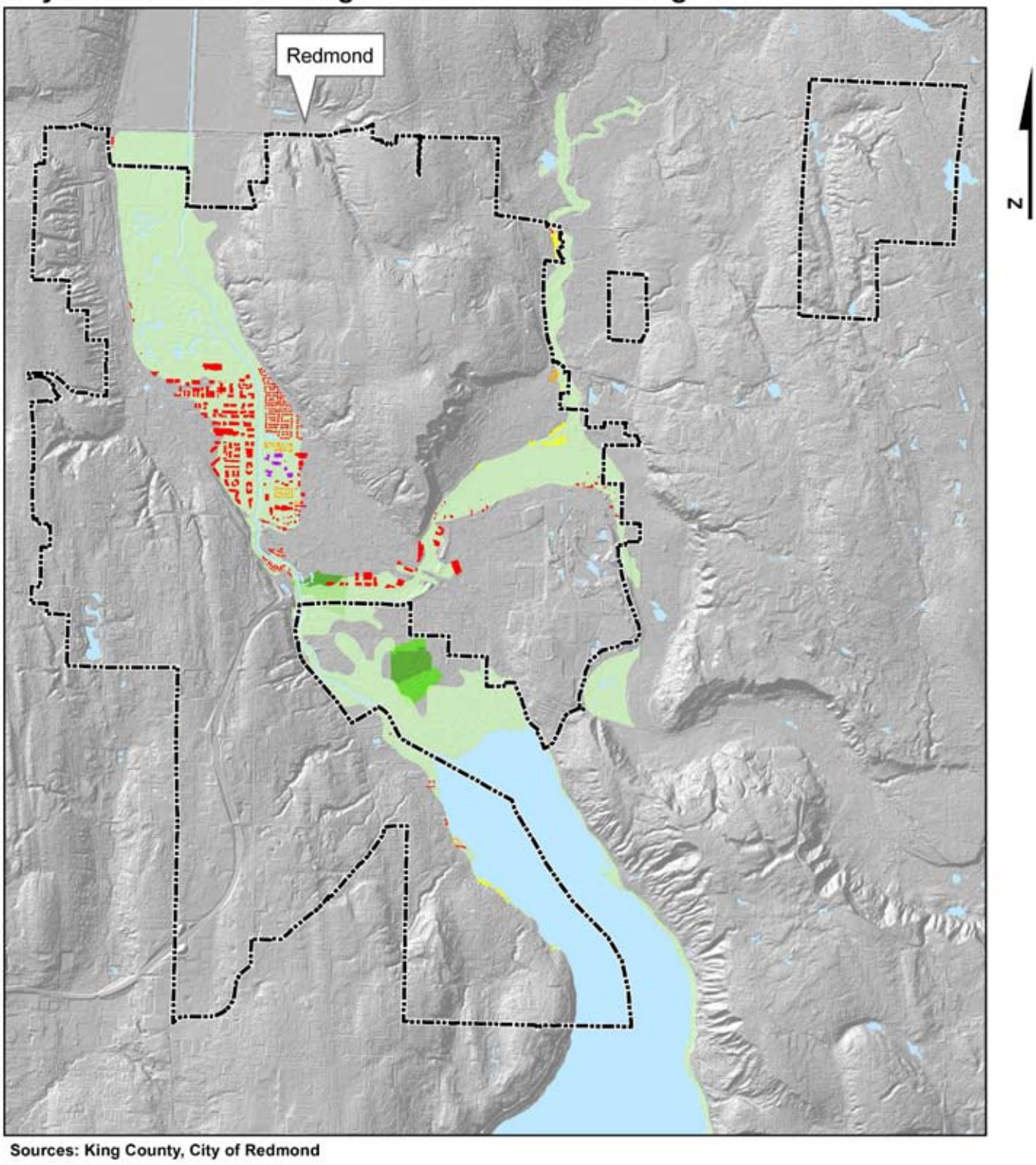


Map 16: City of Redmond 100-Year Floodplain and Chronically Flooded Areas

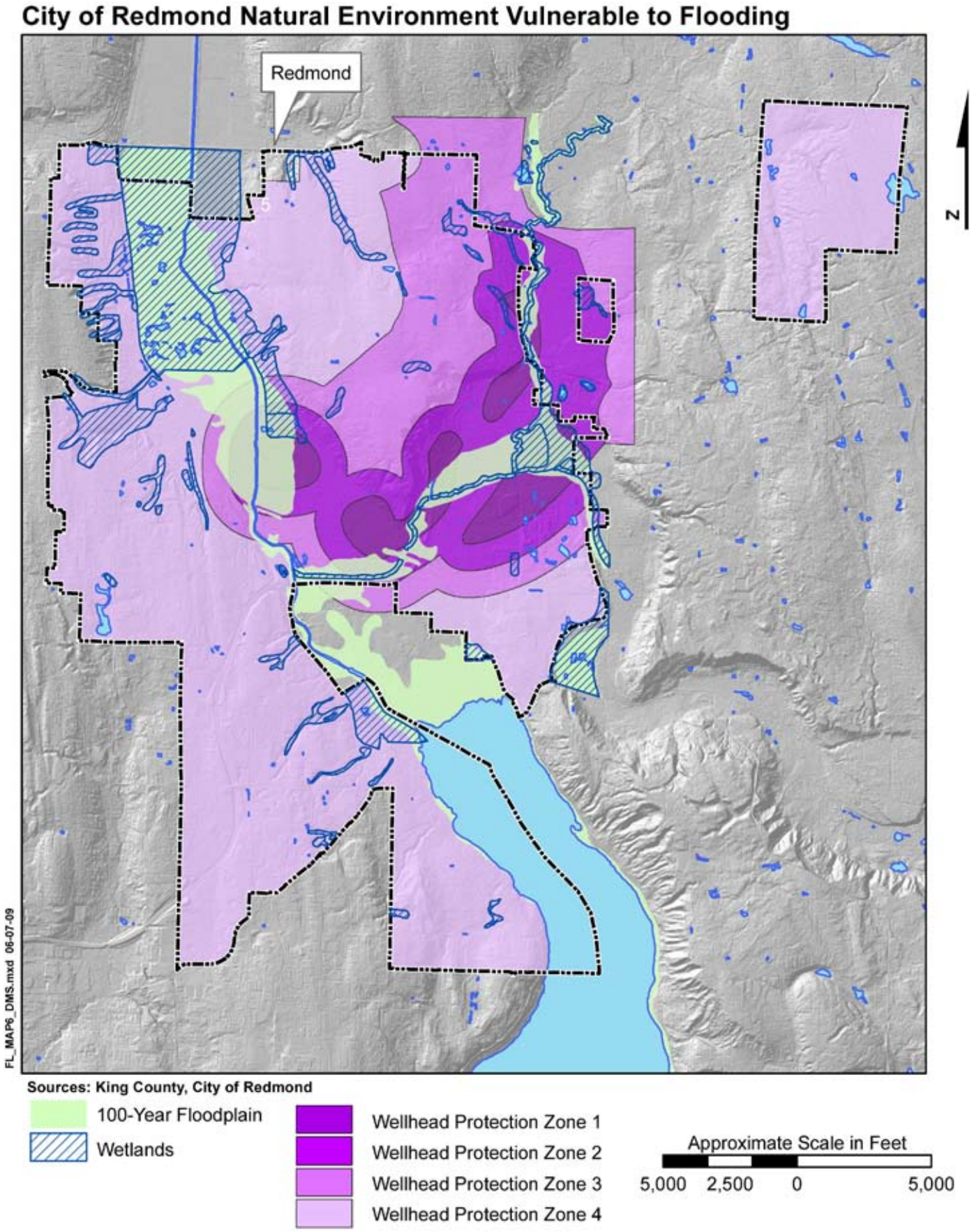


Map 17: City of Redmond NFIP Claims and Holders

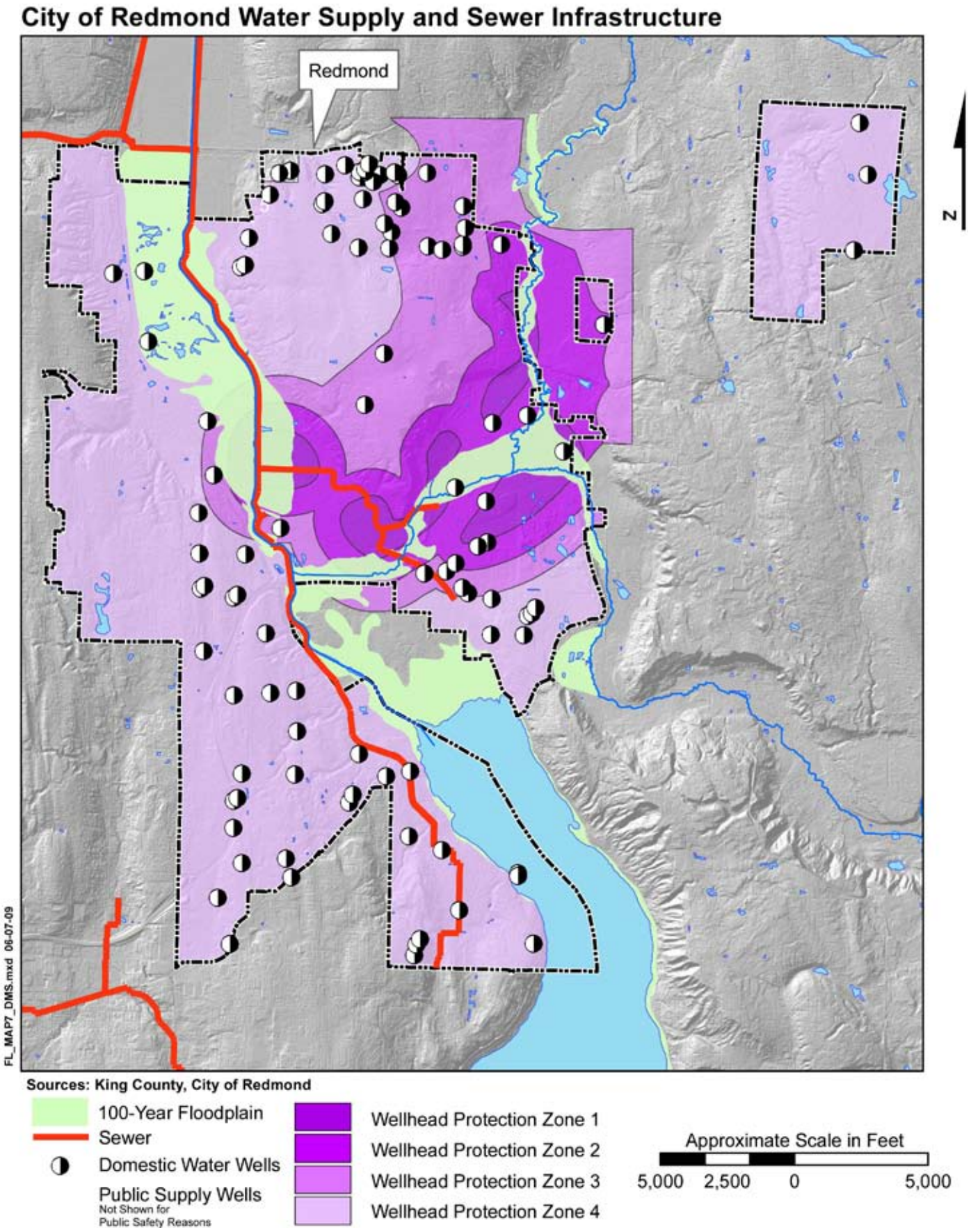
City of Redmond Buildings Vulnerable to Flooding



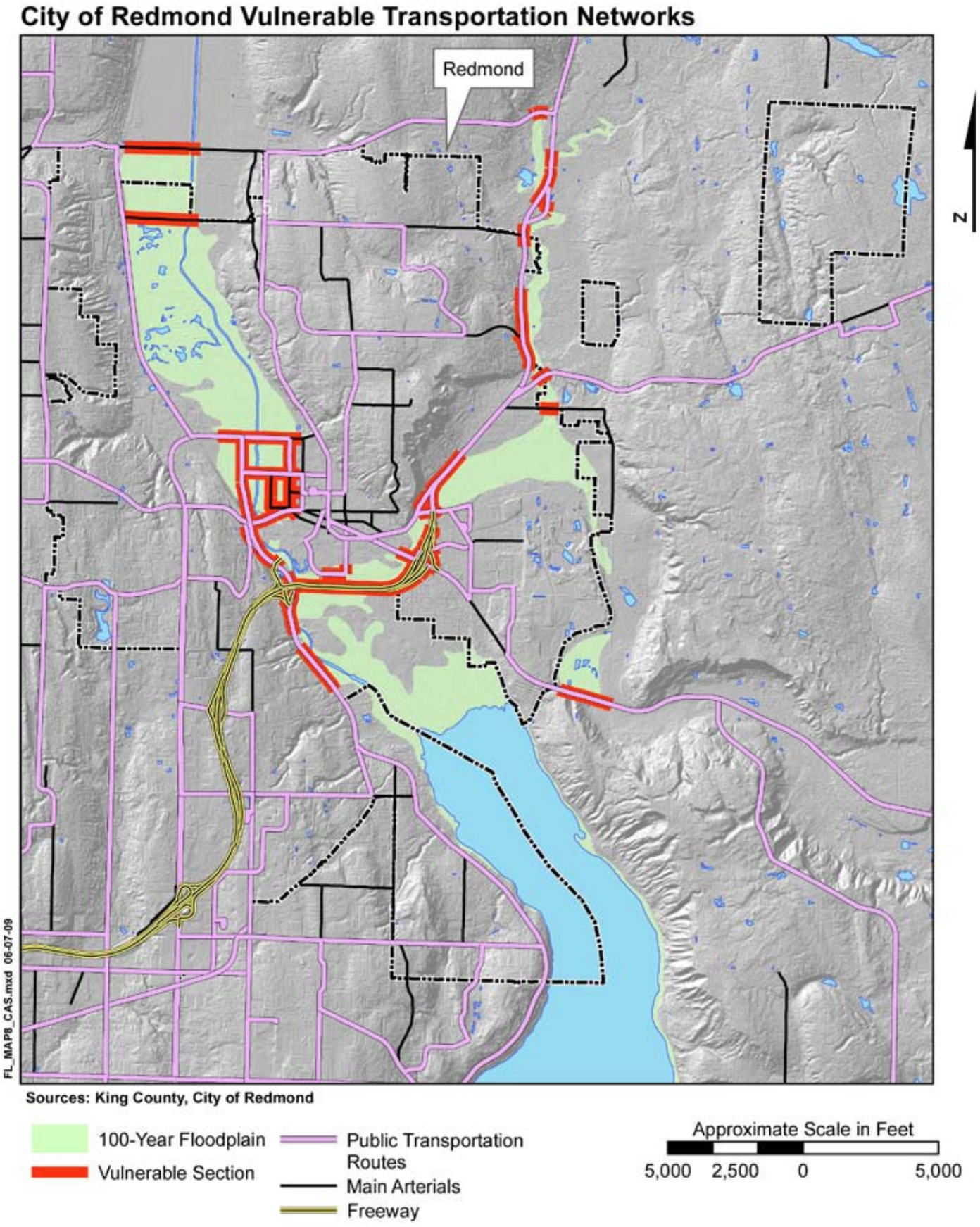
Map 18: City of Redmond Buildings Vulnerable to Flooding



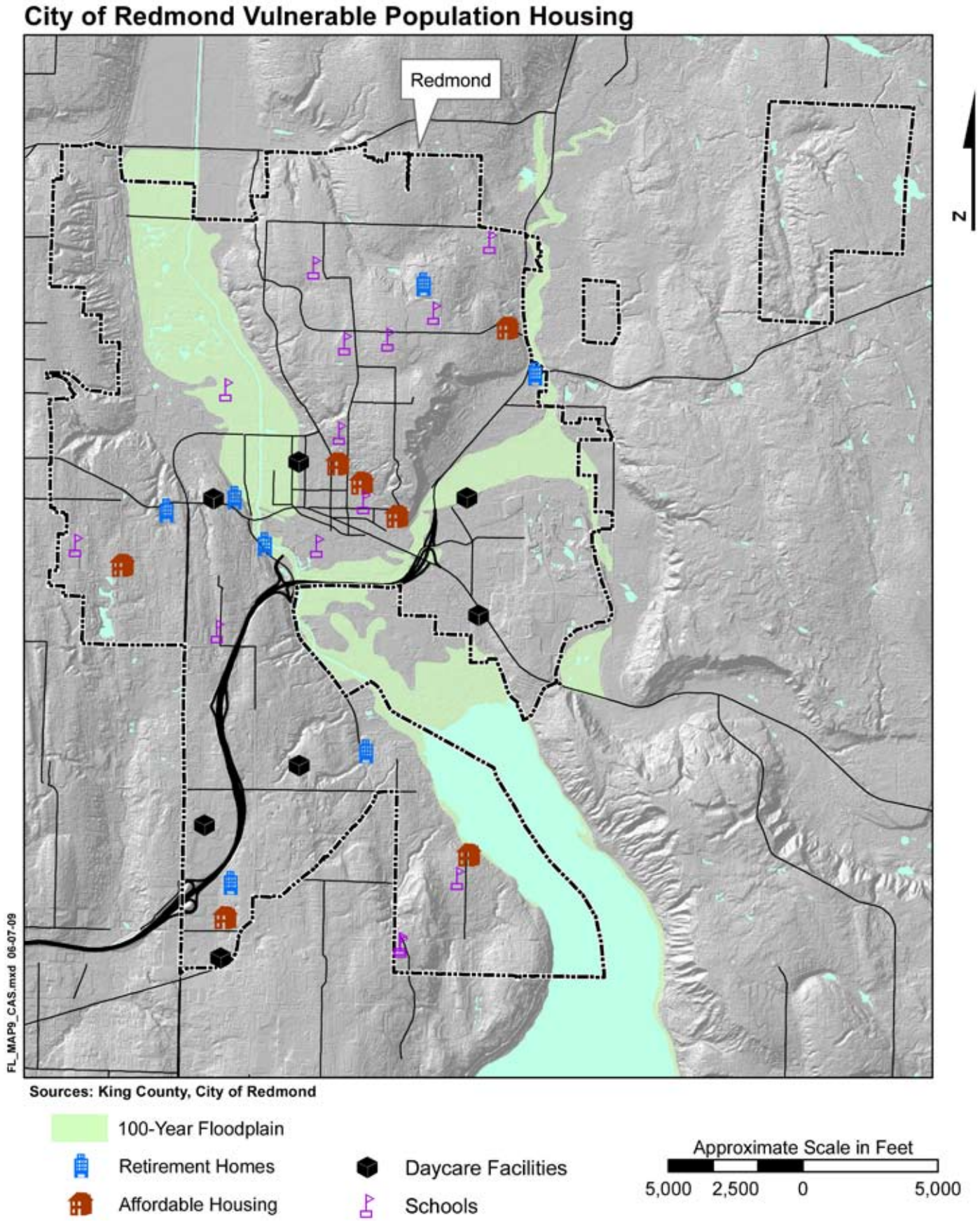
Map 19: City of Redmond Natural Environment Vulnerable to Flooding



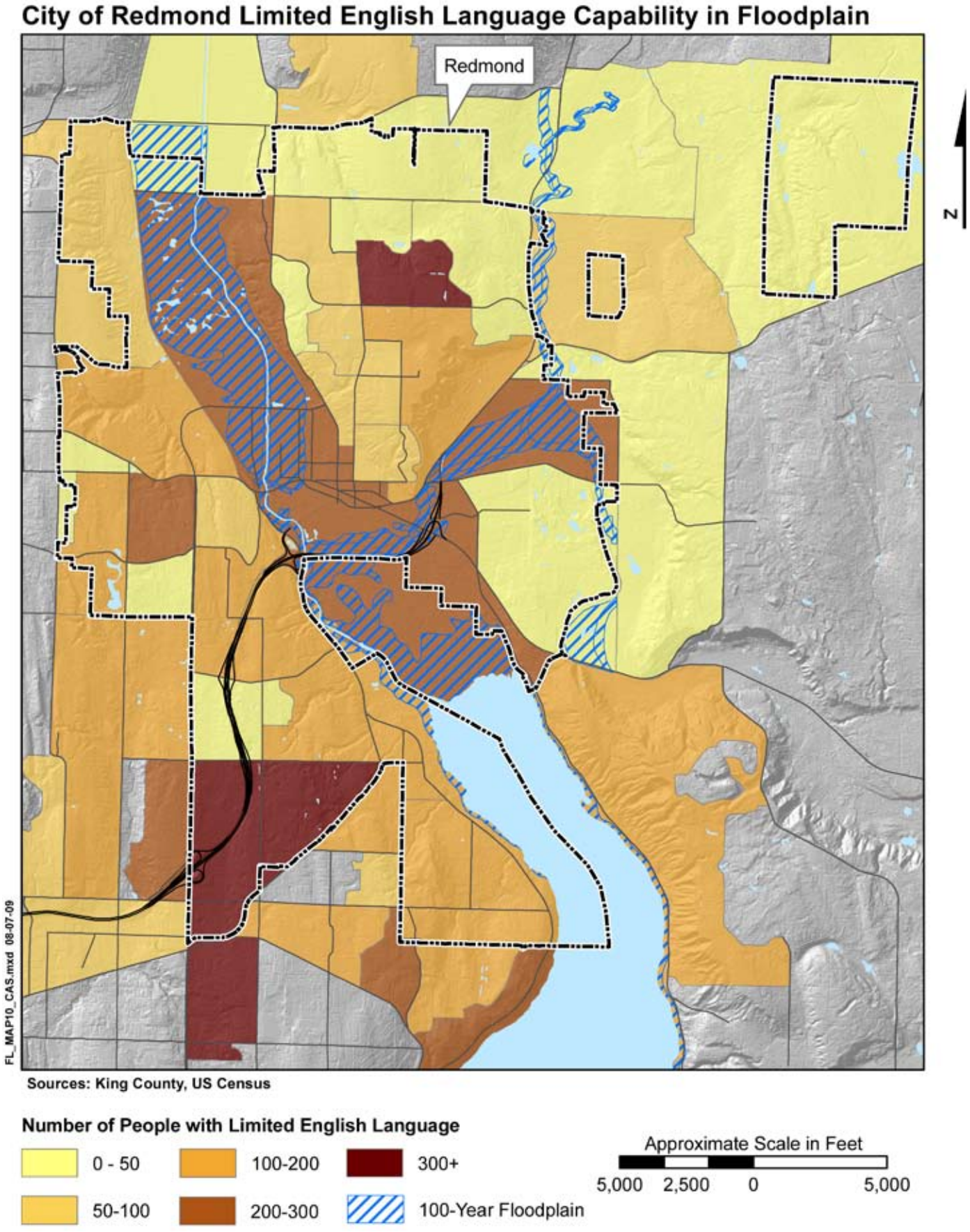
Map 20: City of Redmond Water Supply and Sewer Infrastructure



Map 21: City of Redmond Vulnerable Transportation Networks



Map 22: City of Redmond Vulnerable Population Housing



Map 23: City of Redmond Limited English Language Capability in Floodplain

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Wildfires Risk Assessment

This plan is an update of the 2004 City of Redmond Hazard Mitigation Plan (HMP). Although it is an update, this document has been redesigned so that it looks, feels, and reads differently than the original. This is due to several factors: new hazard information has become available that drives new definitions of risk, the City has matured and new capabilities are now available, and the new format will allow readers to more easily understand the content. In addition, the 2004 HMP included several action items that have been completed, creating an opportunity for developing new mitigation strategies.

7.1 Identify Wildfires Hazards

A wildfire is natural or human caused uncontrolled burning of vegetative fuel such as grasslands, trees, or woodland.[72] A wildfire that encroaches into or develops in areas such as residential neighborhoods or business districts is an urban/wildland interface fire.[73] As Redmond increases development in more open and undeveloped areas, the risk of urban/wildland fires increases.

Careless human activities cause 85% of wildfires in Washington State.[74] Some common human causes include: unattended outside fires, poorly extinguished campfires, fireworks, and cigarette butts thrown into dry vegetation. Naturally occurring fires, such as those sparked by lightning, are rare in Western Washington.[75]

Additionally, east winds have been associated with increased wildfire danger in Western Washington, and often occur due to high-pressure systems that develop in the State's interior during late summer and early fall. When these systems and wind conditions occur, a dry, continental air mass affects western Washington, interrupting the usually damp, humid weather conditions.

Wildfires and urban/wildland interface fires can often be a secondary hazard to drought.[76] Droughts will result in drier canopy cover and increase the amount of available fuel for wildfires. A problem with the Olympic Pipeline could cause a fire or in the case of a fire, a leak from the Olympic Pipeline could exacerbate the magnitude of an existing fire.

72 Emergency Management Division, "Wildfire," Washington Military Department, http://www.emd.wa.gov/hazards/haz_wildfire.shtml.
73 Office of Emergency Management, "Hazards and Disasters: Fire," King County, http://www.kingcounty.gov/safety/prepare/residents_business/Hazards_Disasters/Fire.aspx; and Resource Protection Division, "Wildfire Awareness," Washington State Department of Natural Resources, http://www.dnr.wa.gov/RecreationEducation/Topics/PreventionInformation/Pages/rp_prevent_wildfireawareness.aspx.
74 Resource Protection Division, "Fire Information & Prevention," Washington State Department of Natural Resources, http://www.dnr.wa.gov/RecreationEducation/FirePreventionAssistance/Pages/Home.aspx.
75 Emergency Management Division, "Hazard Profile – Wildland Fire," Washington Military Department, http://www.emd.wa.gov/plans/documents/WildlandfireNov2007Tab5.10.pdf.
76 Emergency Management Division, "Wildfire," Washington Military Department, http://www.emd.wa.gov/hazards/haz_wildfire.shtml.

Climate Change
Climate change trends will significantly increase the chance of both drought and periods of severe heat. As weather patterns change and less moisture is present, foliage and canopy covers become more susceptible to wildfires. This change will increase both the severity and frequency of wildfires in the City of Redmond.[77]

7.2 Profiling Wildfire Hazard Events

A. Location
Although Redmond currently has a low risk for wildfire and urban/wildland interface fires,[78] steep slopes with dense canopy are most at risk of a fire. Vegetation is the primary fuel for both types of fires, and because fire spreads more rapidly uphill than on flat terrain, steep slopes increase this risk. **Map 24, City of Redmond Areas of High Wildfire Risk**, shows the locations in Redmond with the greatest fire risk.

An additional factor for Redmond to consider is the location of the Olympic Pipeline, on the western edge of the City. A fire combined with a leak in the Olympic Pipeline would cause extensive damages. As illustrated in Map 24, there are portions of the pipeline that overlap with fire hazard areas.

B. Timing and Duration
Fire season for Washington State is typically early July to September or October, when the weather is the driest. This fire season tends to apply more to the eastern part of the State, which has a drier climate than Western Washington.[79] Redmond's location west of the Cascade Mountains experiences a damper climate than that of Eastern Washington.[80] This damper climate shortens Redmond's fire season.

C. Severity
The severity of both wildfires and urban/wildland interface fires is influenced by topography, vegetation, development patterns, the use of flammable landscaping and construction materials, and weather conditions. The severity of fires in Redmond varies depending on the type of fire.

A wildfire, primarily fueled by natural vegetation, can have a major impact in areas with dense canopy coverage, specifically areas of more undeveloped land. The severity of an interface fire will increase as urban development encroaches into areas previously undeveloped. Development may decrease the risk of wildfire, but the risk of interface fires will increase. As development continues, the man-made structures will provide fuel for fire and increase the severity of urban/wildland fires.[81]

77 Resource Protection Division, "2020 Strategic Plan for Wildland Fire Protection," Washington State Department of Natural Resources, http://www.dnr.wa.gov/RecreationEducation/Topics/FireInformation/Pages/rp_fire_2020strategicplan.aspx.
78 Resource Protection Division, "Communities at Risk," Washington State Department of Natural Resources, http://www.dnr.wa.gov/Publications/rp_burn_communitiesatrisk.pdf.
79 Emergency Management Division, "Wildfire," Washington Military Department, http://www.emd.wa.gov/hazards/haz_wildfire.shtml.
80 Resource Protection Division, "Fuel Moisture Graphs," Washington State Department of Natural Resources, http://www.dnr.wa.gov/SiteCollectionImages/Places/rp_fire_coast.jpg.
81 Resource Protection Division, "2020 Strategic Plan for Wildland Fire Protection," Washington State

D. Frequency

Previous Occurrences

There has not been a significant urban/wildland interface fire recorded in King County since 1900.[82]

Although the City of Redmond is not responsible for maintaining the Olympic Pipeline, it is important to consider the risk that the pipeline poses. Historically, there have been two serious pipeline-related fires in the Puget Sound Region. These incidents, in Bellingham (1999) and Renton (2004), resulted in major damage, significant injuries, and loss of life. There have not been any pipeline incidents in Redmond.

Probability of Future Events

Climate change will make Western Washington summers drier, thus increasing the risk of fire. New development in previously wooded or undeveloped areas, specifically in areas of high risk for wildfires, will increase the risk of urban/wildland interface fires.[83]

7.3 Assessing Wildfires Vulnerability

7.3.1 Overview

Redmond's vulnerability to wildfires is primarily concentrated on steep slopes with dense vegetation. Because wildfires spread so rapidly in these areas, plants and animals will have little time to react. Additionally, many of these areas of dense canopy cover on steep slopes contain excess dead and dry underbrush, which acts as fire propellant and can increase the intensity of a fire.[84]

Homes near, or adjacent to, areas vulnerable to wildfires will have a higher risk of an urban/wildland interface fire. A fast-moving wildfire moving up a steep slope will quickly engulf a building at the top of the slope if the building is not adequately protected from fire. Thus, buildings and populations near areas with risk of wildfire will be more vulnerable to an urban/wildland fire.

7.3.2 Profiling the Vulnerabilities

A. Man-made

During urban/wildland interface fires, man-made structures are at risk of being destroyed. Geospatial analysis was used to evaluate the number of buildings located in areas of steep slope and dense canopy coverage. As Redmond continues to grow,

Department of Natural Resources, http://www.dnr.wa.gov/RecreationEducation/Topics/FireInformation/Pages/rp_fire_2020strategicplan.aspx.

82 Emergency Management Division, "Hazard Profile – Wildland Fire," Washington Military Department, http://www.emd.wa.gov/plans/documents/WildlandfireNov2007Tab5.10.pdf.

83 Resource Protection Division, "2020 Strategic Plan for Wildland Fire Protection," Washington State Department of Natural Resources, http://www.dnr.wa.gov/RecreationEducation/Topics/FireInformation/Pages/rp_fire_2020strategicplan.aspx.

84 Emergency Management Division, "Hazard Profile – Wildland Fire," Washington Military Department, http://www.emd.wa.gov/plans/documents/WildlandfireNov2007Tab5.10.pdf.

and more structures are built on undeveloped land, the vulnerability of man-made structures will increase.

Table 15 shows the number and type of buildings located on steep vegetated slopes. As Redmond continues to grow, the currently vacant parcels will be developed and increase the number of vulnerable buildings.

Overland Fire Risk	
Type of Use	**Buildings**
Non-Residential	228
Multifamily	45
Single Family	513

Table 15: Number and Type of Buildings Vulnerable to Urban/Wildland Interface Fires
Source: Calculated from Washington State Geospatial Data Archive, "King County Data," University Libraries: University of Washington, http://wagda.lib.washington.edu/.

B. Natural

As previously noted, areas of dense canopy cover are extremely vulnerable to wildfire, particularly on steep slopes. A fire can temporarily alter or destroy a wooded habitat. Since fires are part of a natural cycle, the environment will recover from such a disturbance. However, urban development has made more species vulnerable, thus decreasing their resilience to a major disturbance such as a fire. Fires may also change the sedimentation and temperatures in rivers, stressing aquatic habitats.

C. Systems

Roads may be closed during a fire. Road closures may isolate neighborhoods and complicate evacuations. **Map 25, City of Redmond Roads Vulnerable to Wildfires**, highlights the sections of roads that may be compromised in a wildfire.

Although most utility lines are underground in Redmond, above ground electric transmission lines and cell towers may be impacted during an interface fire.

D. Populations

Map 26, City of Redmond Fire Risk and Vulnerable Populations, shows the location of facilities that concentrate vulnerable populations.

Hazard Specific

People who live or work near or in the fire hazard zone will face increased risk in the event of a fire.

Isolated Populations

People that live on, near, or require access through fire zones may become isolated during a fire. In the event of a large fire, compromised accessibility will complicate evacuation efforts.

Disabled Persons
People with limited mobility may experience additional difficulty in the event of a quick evacuation.

Children
Young people that are separated from their families may have limited mobility and insufficient knowledge about how to respond to a fire.

Elderly
Elderly people are more vulnerable to a fire if they have limited mobility or access to medical care. The elderly are more likely to have a compromised immune system and may have difficulty breathing smoke-filled air.

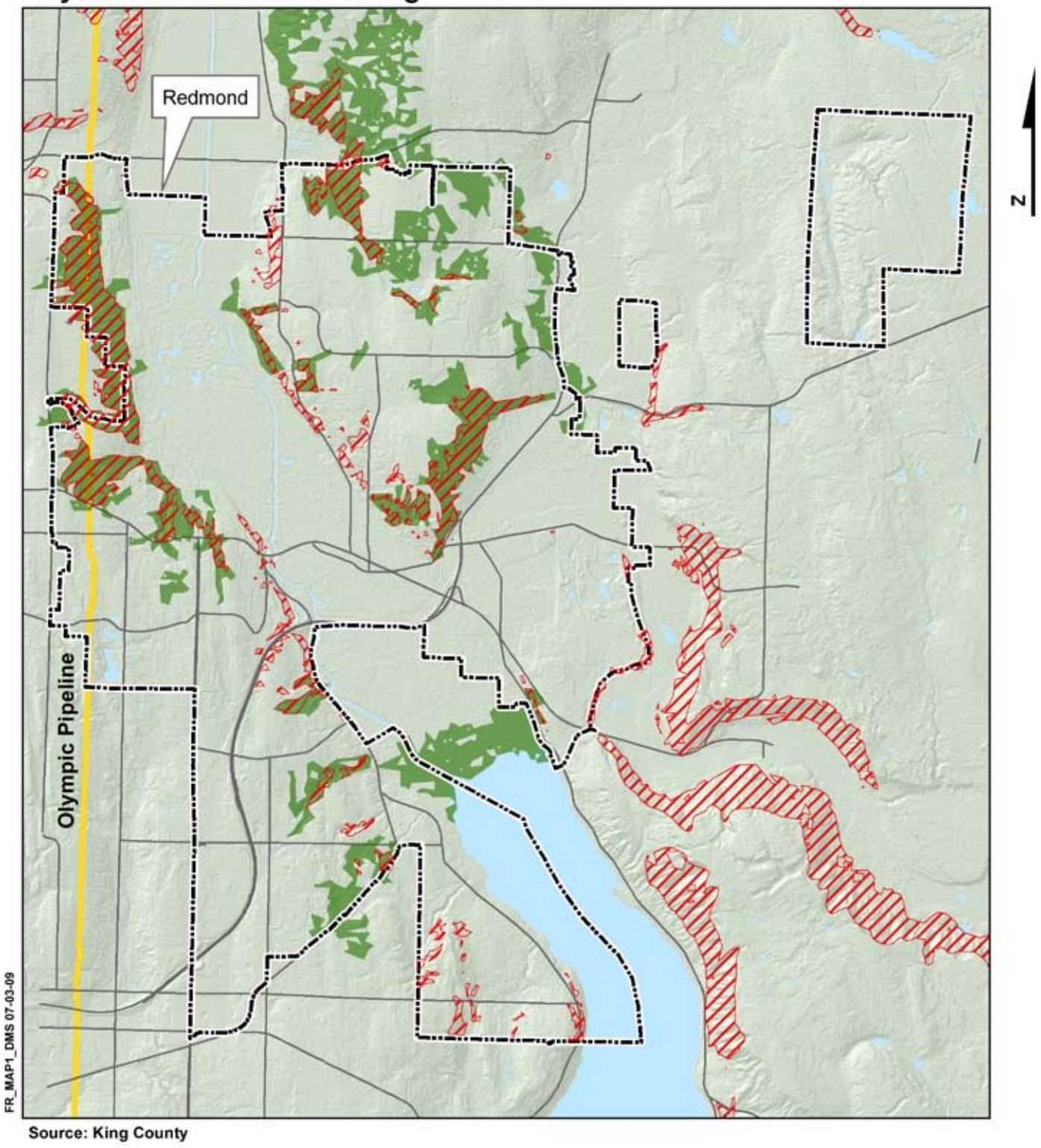
Limited English Language
People with limited English Language may not have sufficient access to mitigation or preparedness activities. Additionally, emergency announcements may not be adequate without translation.

Low-income Residents
People with limited financial resources may be more vulnerable to the potential losses from a fire.

7.3.3 Analyzing Development Trends

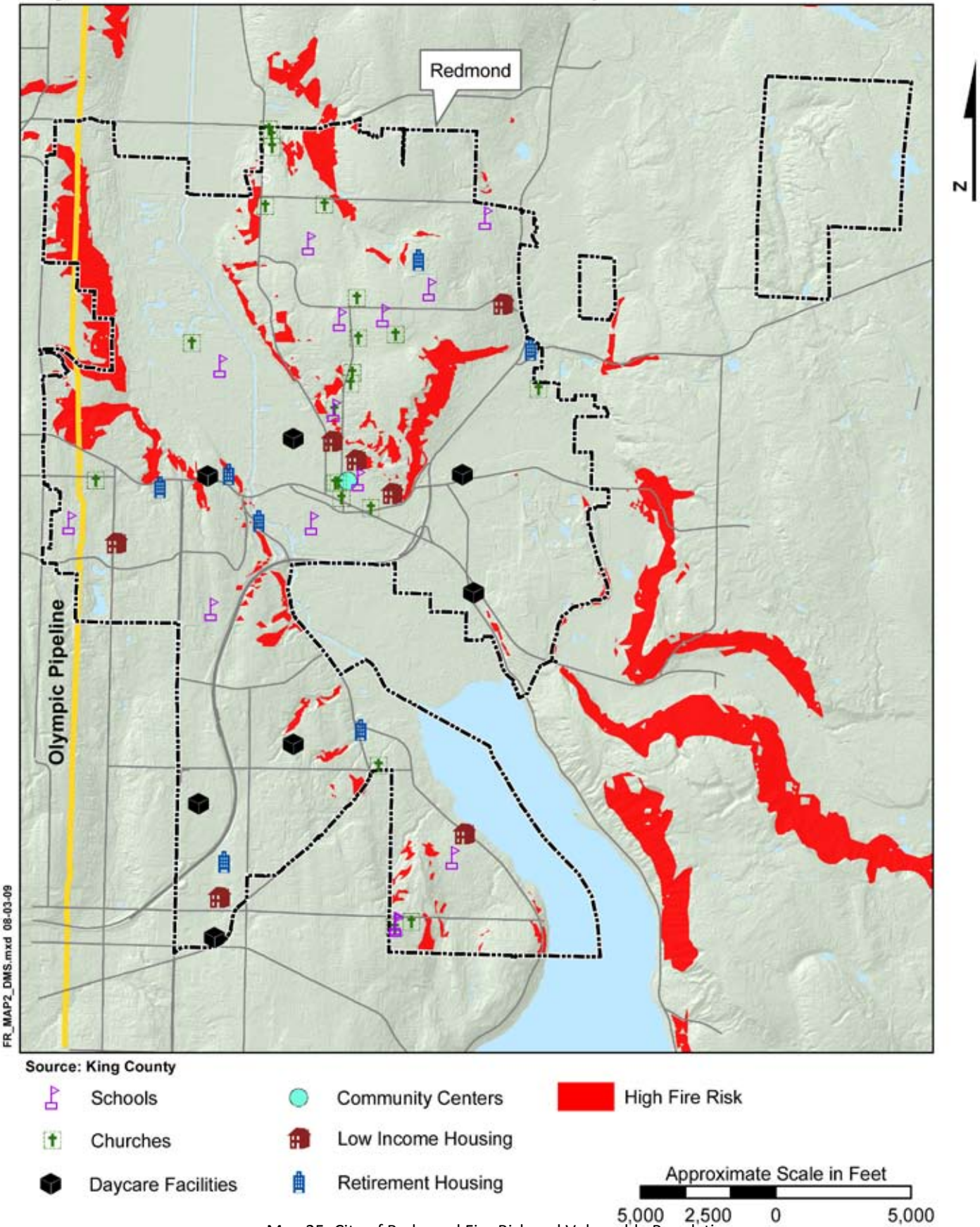
As the greater Puget Sound Region continues to grow the City of Redmond will see a population increase within the City boundaries and in nearby jurisdictions. As new development pushes into previously undeveloped areas the risks from urban/wildland interface fire will increase. As weather patterns intensify due to climate change, previously damp conditions west of the Cascade will experience drier summers, increasing potential fuel sources for wildfires and urban/wildland interface fires.

City of Redmond Areas of High Wildfire Risk



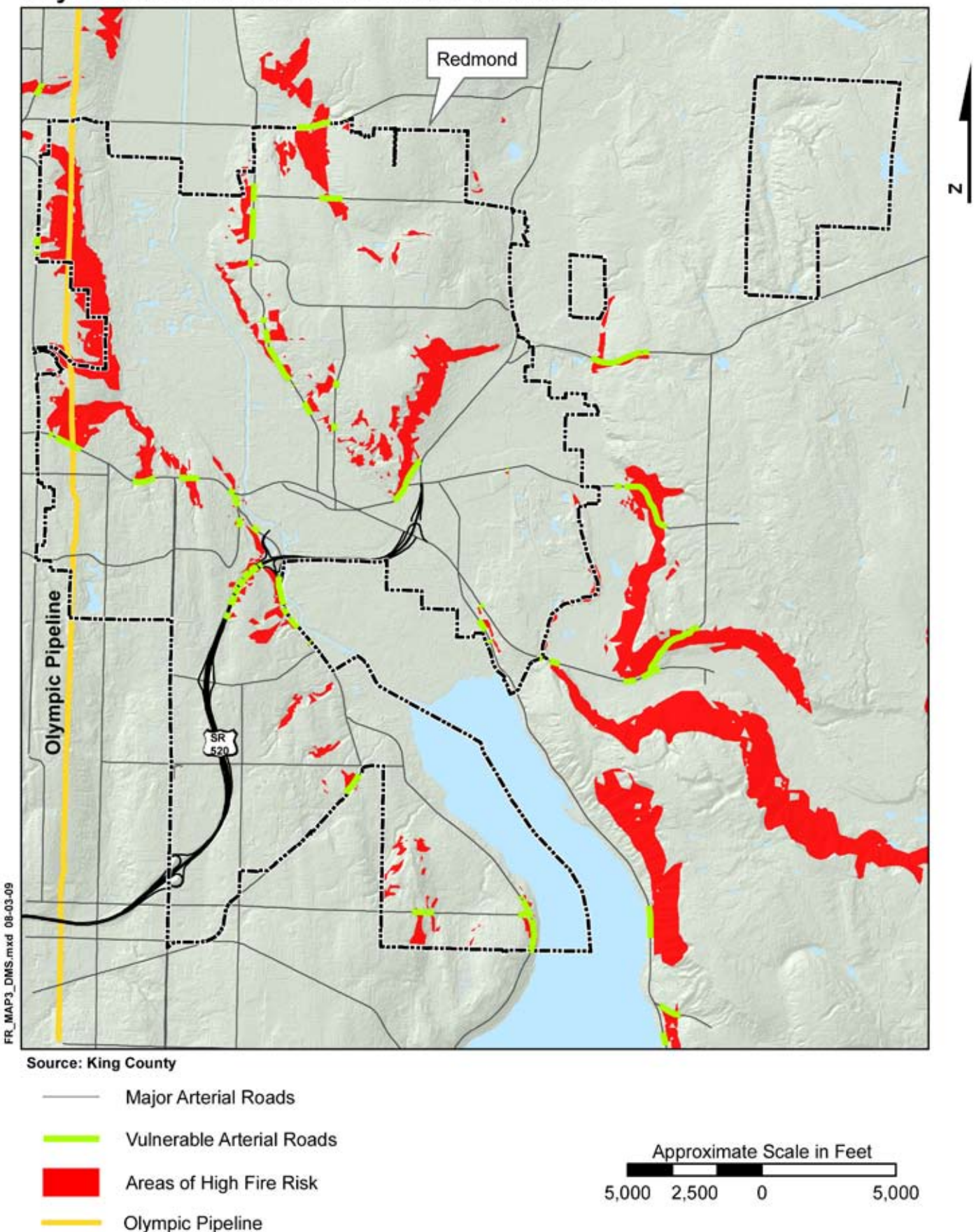
Map 24: City of Redmond Areas of High Wildfire Risk

City of Redmond Fire Risk and Vulnerable Populations



Map 25: City of Redmond Fire Risk and Vulnerable Populations

City of Redmond Roads Vulnerable to Wildfires



Map 26: City of Redmond Roads Vulnerable to Wildfires

Landslides Risk Assessment

This plan is an update of the 2004 City of Redmond Hazard Mitigation Plan (HMP). Although it is an update, this document has been redesigned so that it looks, feels, and reads differently than the original. This is due to several factors: new hazard information has become available that drives new definitions of risk, the City has matured and new capabilities are now available, and the new format will allow readers to more easily understand the content. In addition, the 2004 HMP included several action items that have been completed, creating an opportunity for developing new mitigation strategies.

8.1 Identify Landslide Hazards

A landslide is a movement of debris down a steep slope. The speed of the moving debris will vary from a slow creeping motion to a high-speed moving mass. Landslides are caused by a combination of factors, including geology, gravity, weather, and human activity. The steepness of a slope and the forces of gravity acting upon it are the main contributing forces of a landslide. For alluvial soils, on which much of Redmond sits, the angle of repose (the point at which a slope becomes unstable) is estimated to range from 30-35 degrees. Therefore, hillsides with a slope of greater than thirty degrees are landslide hazards. [85]

Landslides occur when the soil is saturated, causing instability on hillsides. Saturated steep slopes may give way and pose a threat to the area on and near the hillside. Landslides may also occur as a secondary hazard after an earthquake or a severe storm. An earthquake during an extended period of rain would likely cause landslides. A large landslide that falls into Lake Sammamish could cause a seiche.

Factors that increase the likelihood of a landslide:

- Undercutting of a stream into a hillside
- Soil erosion/makeup
- Improper drainage on hillside
- Earthquakes
- Fires
- Intense periods of precipitation
- Lack of vegetation
- Improper development and drainage practices
- Alternate freezing and thawing

Landslides vary in both speed and size. The moving mass may be as narrow as a few feet or as wide as a few miles. Trees, roads, bridges, and homes may be swept away in the slide.

85 Carson, M.A. and Kirkby, M.J., *Hillslope Form and Process*. West Nyack, New York, U.S.A. Cambridge University Press,1972.

Climate Change
Climate change will increase the risk of landslides by exacerbating some of the factors listed above, such as increased precipitation events or vegetation-destroying wildfires.

8.2 Profiling Landslide Hazard Events

A. Location
Landslide hazard areas in Redmond are identified as slopes greater than thirty degrees and the areas within a fifty-foot buffer above and below such slopes. Steep slopes in Redmond are located primarily on the western and southeastern portion of Education Hill and along Redmond's northwestern border in the Willows/Rose Hill neighborhood.

Beyond the City limits there are several steep slopes surrounding Lake Sammamish and lining the Sammamish Plateau. A landslide on the slopes surrounding Lake Sammamish could result in a seiche. A seiche, sometimes called a lake tsunami, is an oscillating wave that occurs in an enclosed or semi-enclosed body of water.

Map 27, City of Redmond Landslide Hazard Areas and Major Vegetation, shows the hazard area along with the 50 foot buffer area. The King County Critical Areas Ordinance (CAO) designates critical slopes as hillsides with a slope of at least forty percent (approximated 21 degrees inclination) that are taller than ten feet. The CAO also includes a fifty-foot buffer (which can be waived for single family housing).[86]

B. Timing and Duration
Soil saturation occurs primarily in the winter or spring, during Redmond's wettest months. Prolonged heavy rain will typically provide a few days warning prior to a slide. Signs of increased slope instability may indicate slopes that are most vulnerable during a particularly wet season. Irregular tree angles may present warning signs of past landslide occurrences. Close monitoring of structures built on or near the slopes may provide early indications of slides.

Slides can be slow, moving a couple of millimeters a year, or as fast as 200 miles per hour. Typical slides move at a rate of 30-50 miles per hour.[87] As a result of the fast movement, landslides are generally short in duration.

C. Severity
The speed of landslides can cause damage to structures and injure people. Slopes that are protected by the CAO remain in a natural, vegetative state, providing some ground stability. However, development and habitat alteration above the slopes may change the natural drainage patterns of stormwater run-off. While few structures appear to be constructed mid-slope (construction prior to the 1990 CAO were grandfathered in[88]) on any of the steep hillsides in Redmond, some structures have

86 King County Critical Areas Ordinance, "Chapter Two - Steep Slopes Hazard Area," King County, http://your.kingcounty.gov/ddes/cao/Manual/II-SteepSlope.pdf.
87 United States Geological Survey, "Landslide Hazards Program," http://landslides.usgs.gov/learning/faq/.
88 King County Critical Areas Ordinance, "Chapter Two - Steep Slopes Hazard," King County, http://your.

been built on the edges above and below steep slopes, and are therefore susceptible to foundation damage and/or complete destruction of the structure by moving debris. **Map 27, City of Redmond Landslide Hazard Areas and Major Vegetation**, shows the steep slopes lacking vegetation.

D. Frequency

Previous Occurrences
Landslides have frequently caused disturbances in King County cities. The storms of 1996 and 1997 caused more than 100 landslides throughout the county. The 2001 Nisqually earthquake triggered a portion of road near Renton, WA to slide into the Cedar River.[89]

Probability of Future Events
Climate change forecasts warn of an increase in frequency and severity in precipitation; thus landslides in Redmond are likely to become more frequent. Increased and intensified development on the hillsides and surrounding areas will change the character of runoff. Increased runoff elevates the landslide threat. Proper drainage practices, hillside terracing, and increased vegetation can stabilize hillsides and reduce the probability of landslides.

8.3 Assessing Landslide Vulnerability

8.3.1 Overview

In the United States, landslides cause 25-50 deaths and over $1 billion in damages annually.[90] The built environment and drainage culverts are likely to be vulnerable during a landslide. Delicate fish and wildlife habitat will also be vulnerable to a landslide. Since landslides will happen in isolated areas, damage will be location specific.

8.3.2 Profiling the Vulnerabilities

A. Man-made
Redmond's natural geologic slopes and development on or near steep slopes make the built environment vulnerable. Approximately 10% of the residential structures in Redmond are located in the landslide hazard zone. About 9.5% of the non-residential (commercial and public) buildings are also within the designated buffer. **Map 28, City of Redmond Buildings in Landslide Hazard Areas**, shows the prevalence and location of commercial and residential structures located on, or within, the 50-foot buffer of slopes that are greater than 30%.

kingcounty.gov/ddes/cao/Manual/II-SteepSlope.pdf.
89 King County Office of Emergency Management, "Landslides," King County, http://www.kingcounty.gov/safety/prepare/residents_business/Hazards_Disasters/Landslides.aspx
90 United States Geological Survey, "Landslides Hazard Program," http://landslides.usgs.gov/learning/ls101.php.

B. Natural

A landslide may increase sedimentation and siltation in waterways, which may negatively impact fish and other wildlife habitat. A landslide may further destabilize a steep hillside and destroy trees and other vegetation, which may also impact wildlife habitat.

C. Systems

Roads and telecommunication networks may be vulnerable to a landslide. The location of the landslide will determine the impact. About 9.5% of the City's stormwater culverts are located within the 50-foot landslide buffer hazard zone. Damaged or blocked culverts may cause additional damage to the transportation system and provide subsequent obstacles for businesses (see **Map 29, City of Redmond Roads and Culverts in Landslide Hazard Areas**).

Slides, similar to earthquakes and other seismic activity, increase the vulnerability of telecommunication networks and infrastructure. Landslides generally impact all built forms and infrastructure within the affected area. Therefore, other utility infrastructure may also have increased exposure to risks if a landslide should take place in proximity to these systems.

Transportation systems are vulnerable to landslides. Damage may limit access for residents and employees in the City of Redmond. Emergency crew access could be limited by a landslide that makes roads unusable.

D. Populations

Refer to **Map 30, City of Redmond Populations Vulnerable to Landslides,** for the locations of vulnerable populations outlined below.

Hazard Specific

People who live or work near a steep slope are vulnerable in the event of a landslide. However, sufficient monitoring during periods of heavy rain may provide sufficient time for evacuation.

Isolated Populations

A landslide may isolate populations that live near a slide area. If a landslide impacts a road, and no alternate route exists, communities may become isolated. Specifically, Education Hill residents may become isolated in the event of a landslide that blocks roads.

Disabled Persons

In the case of a landslide, people with mobility constraints may have difficulty with a rapid evacuation.

Children

Children may become isolated from family members in the case of a landslide that affects the transportation system. Five schools and daycares are located within a

landslide hazards zone.

Elderly
Three retirement homes are located on steep slopes and two are located within close proximity to a steep slope. These facilities may be vulnerable to a landslide.

Limited English Language
Residents that do not have access to landslide hazard information in a language that they understand may not be able to adequately mitigate or have access to emergency information.

Low-income Residents
People with limited resources may not have the means to update their homes or relocate if necessary.

8.3.3 Analyzing Development Trends

The King County and City of Redmond Critical Area Ordinances (CAO) limit development on or near slopes that exceed a forty percent grade (approximately 21 degree incline) and are taller than ten feet. Although the Future Land Use Map of Redmond shows that much of the land in the landslide hazard zones are zoned residential and commercial, the CAO restricts potential development. However, development above and below steep hillsides (beyond the CAO fifty-foot buffer) may have a negative impact on the drainage and stability of the hillside. Development will alter the landslide hazard zone.

8.3.4 Redmond's Landslide History

Redmond has dealt with two significant landslides in their history dating back to 1997. In January, 1997, a severe winter storm (Federal Disaster 1159-DR-WA) caused localized flooding and overwhelmed storm drains and culverts in several locations in the City. A substantial landslide occurred on the southwest side of town when a hillside gave way due to excessive water overflowing storm drains and culverts at the top of the hill. The subsequent slide caused a road to be washed out.

In December, 2001, a water line broke as a result of a private development project at the top of a hillside. The resulting water flow overwhelmed a culvert caused slippage on the adjacent hillside. This slide occurred on the south west side of town off of 24th Ave NE. (See Maps 27, 28). The slide actually occurred on private property.

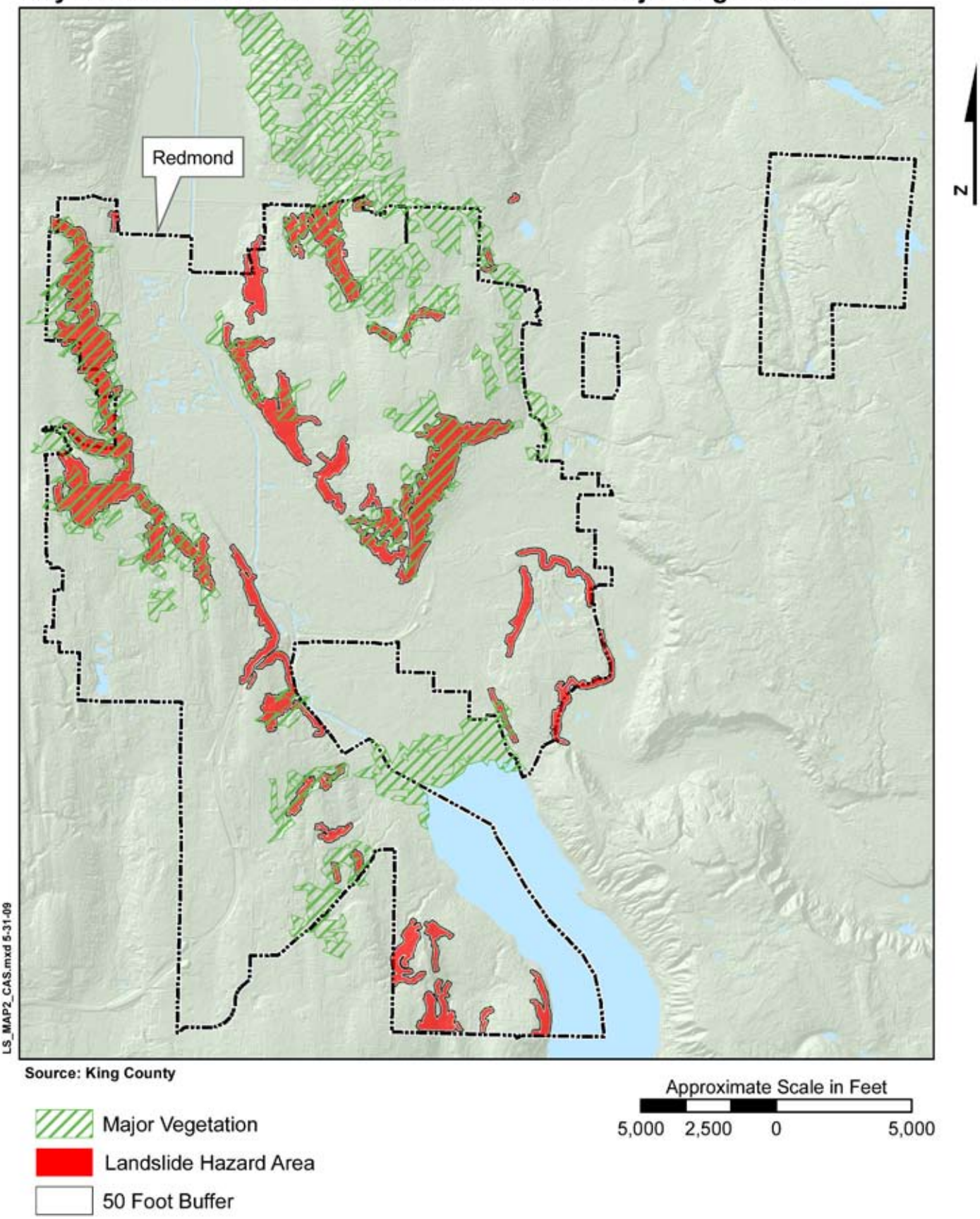
These two landslides listed above have led to a Public Works review of the storm drain capacity in Redmond and some changes to the development codes for residential and commercial development. In addition, Redmond conducted a review of its policy relating to regular street cleaning and storm drain clearing that ultimately included messaging to Redmond residents encouraging them to regularly check storm drains

in their neighborhoods. Redmond has also modified its procedures for monitoring construction during poor weather times to ensure that necessary precautions are taken to keep hillsides stable.

8.4 Scenarios

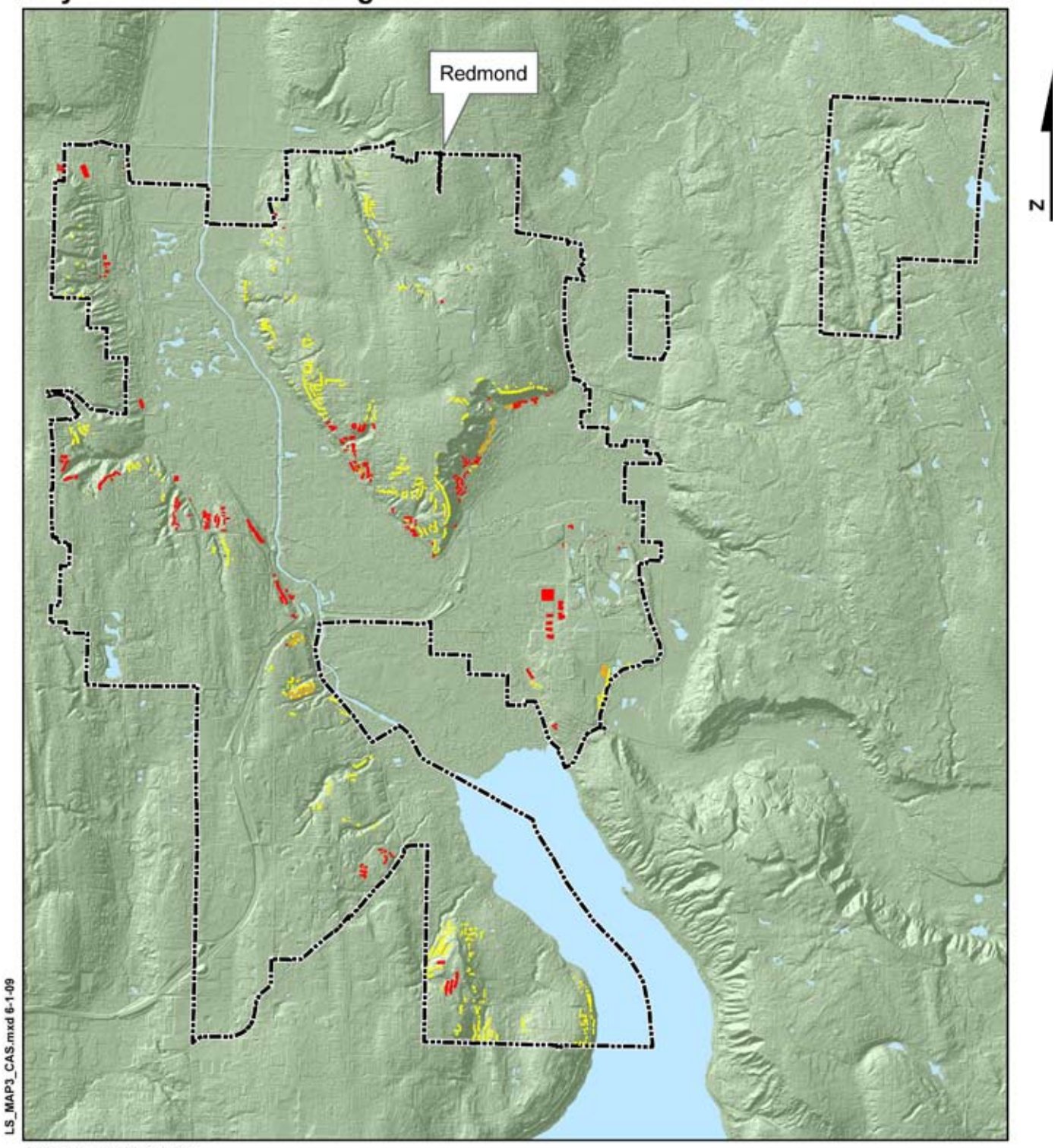
At 10 p.m. on November 5th, after several weeks of rain, a section of hillside in the Education Hill area gave way. Three homes slid fifty feet down the hillside, depositing debris in the backyards of several other homes, which were not damaged directly but lost landscaping and auxiliary structures, such as storage sheds. The residents and the City are cleaning up the large amounts of debris. Five people were injured, but there were no life-threatening injuries. Although neighboring homes are currently stable, monitoring will continue as the section that gave way continues to occasionally crumble. The road above the hill has been closed due to instability. The debris blocked a culvert at the bottom of the hill and caused two feet of flooding on sections of SR-202, Redmond-Woodinville Road. The road was closed for thirty-six hours before crews were able to restore normal traffic flow.

City of Redmond Landslide Hazard Areas and Major Vegetation

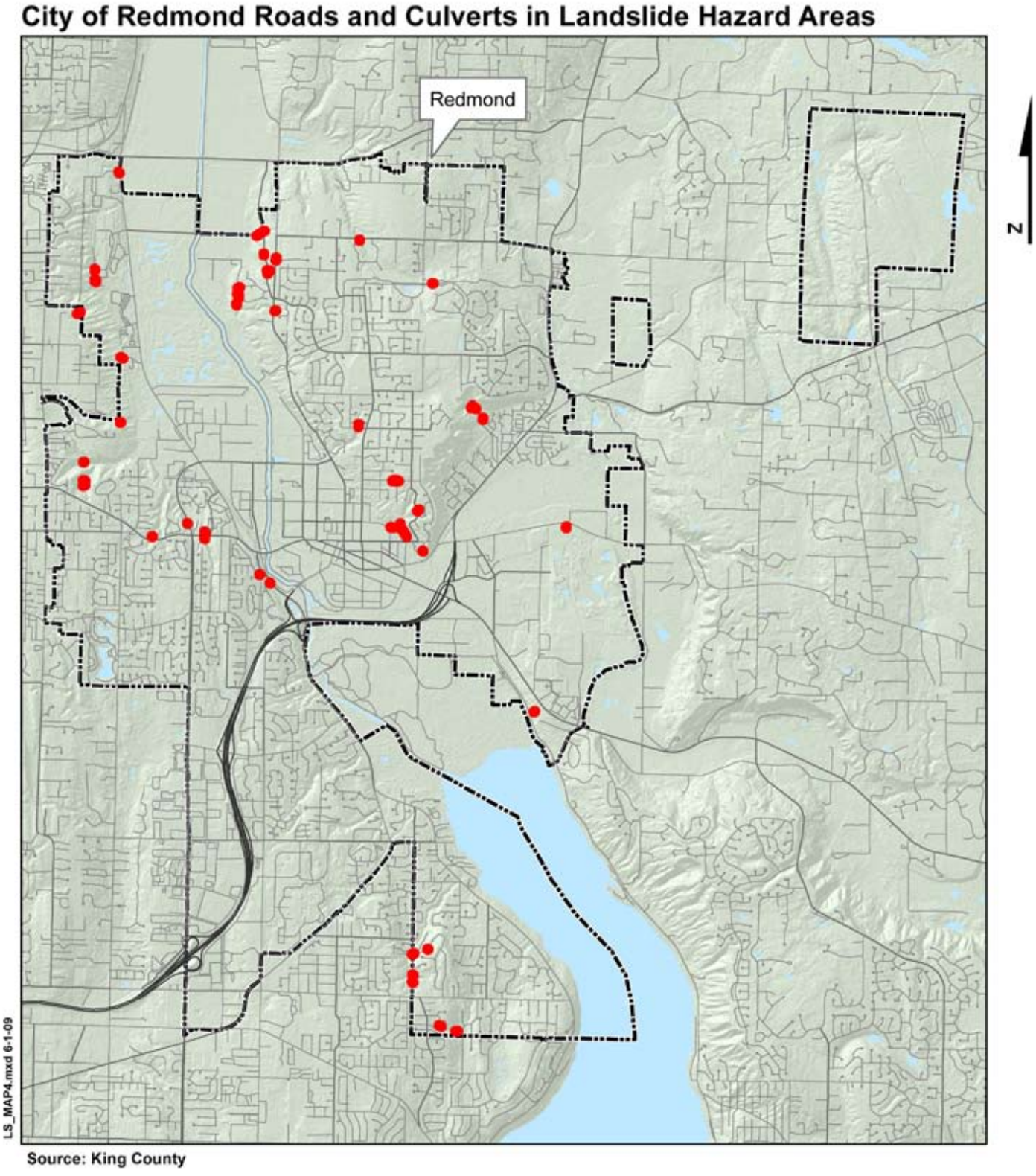


Map 27: City of Redmond Landslide Hazard Areas and Major Vegetation

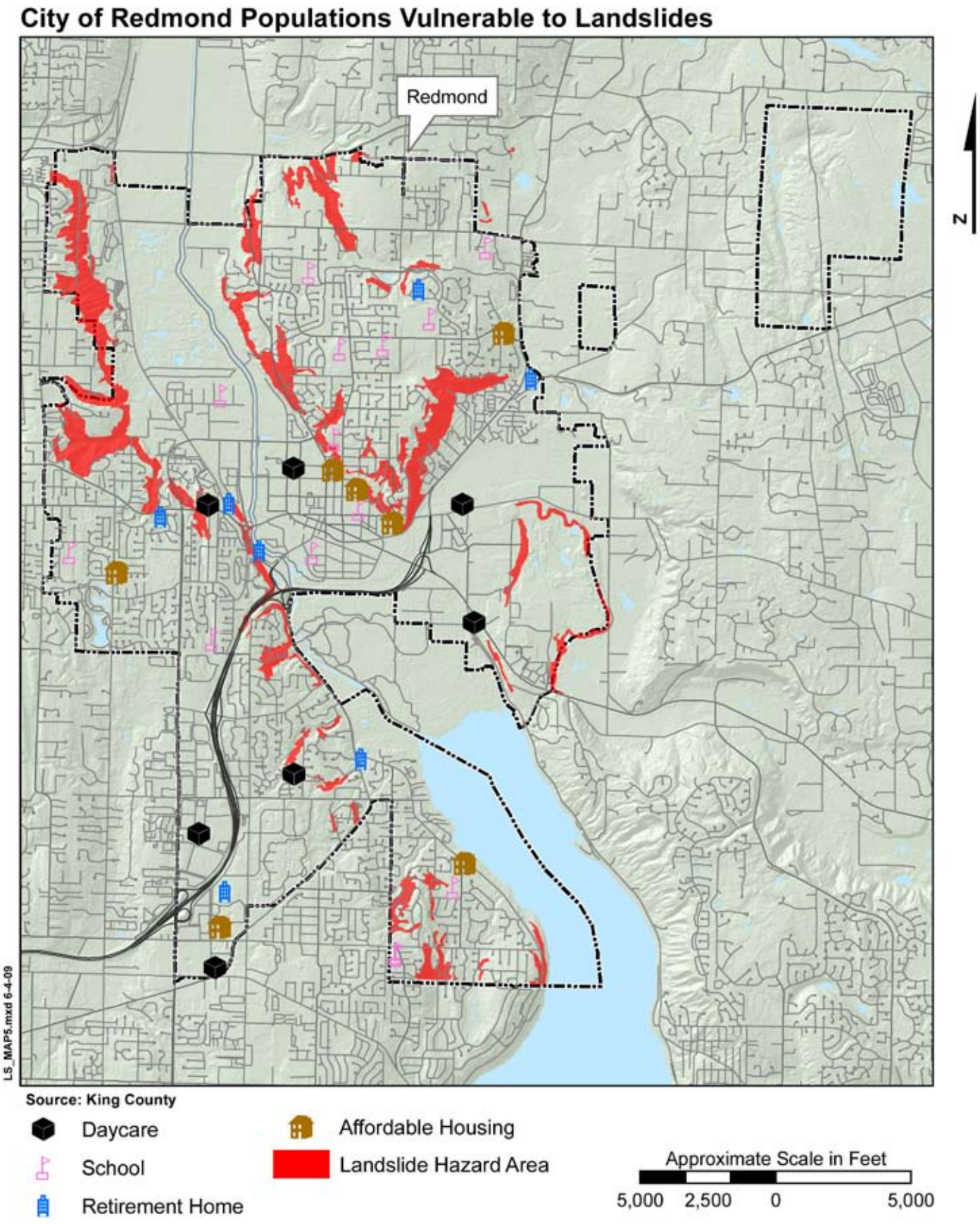
City of Redmond Buildings in Landslide Hazard Areas



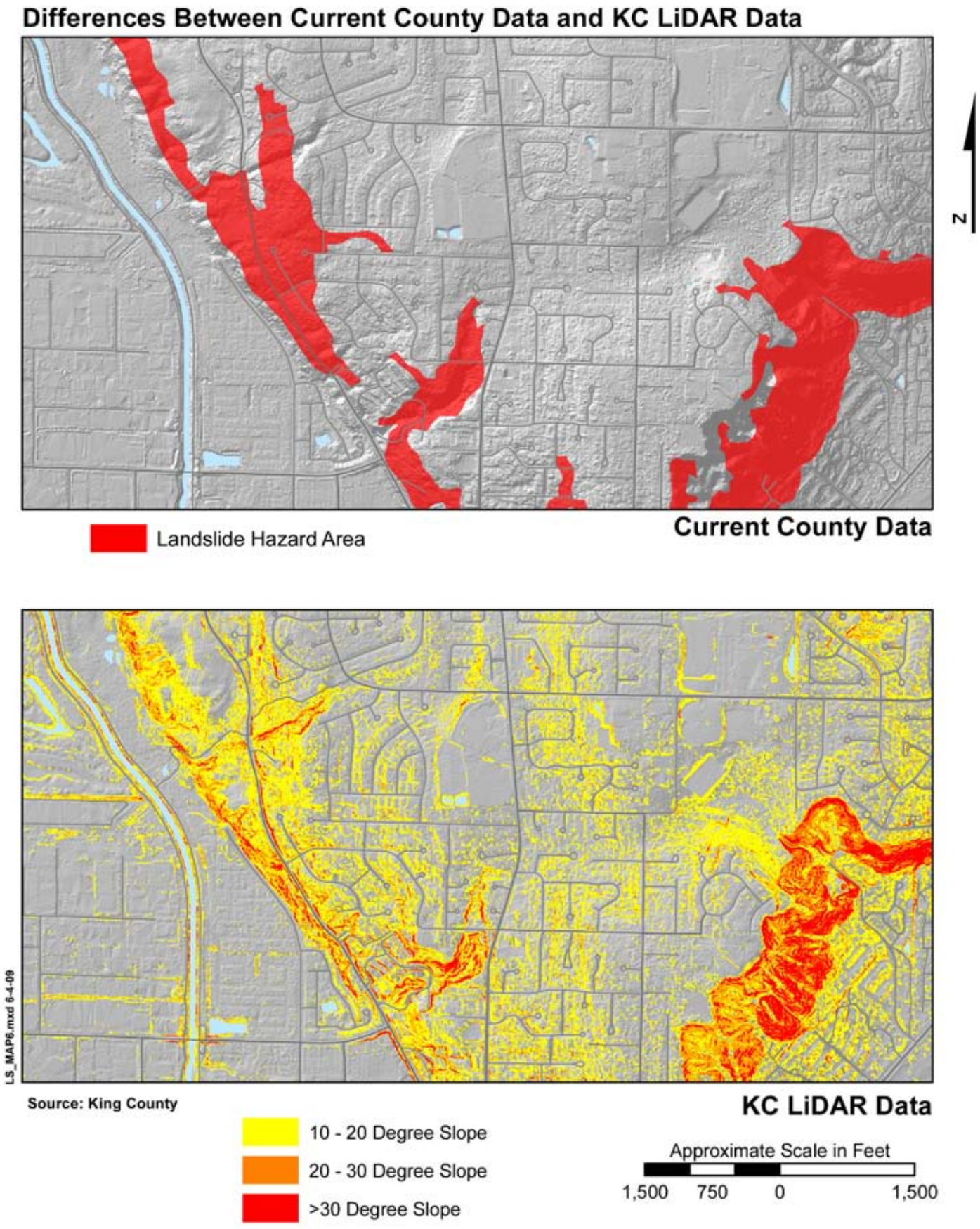
Map 28: City of Redmond Buildings in Landslide Hazard Areas



Map 29: City of Redmond Roads and Culverts in Landslide Hazard Areas



Map 30: City of Redmond Populations Vulnerable to Landslides



Map 31: Differences Between Current County Data and KC LiDAR Data

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Pandemics Risk Assessment

This plan is an update of the 2004 City of Redmond Hazard Mitigation Plan (HMP). Although it is an update, this document has been redesigned so that it looks, feels, and reads differently than the original. This is due to several factors: new hazard information has become available that drives new definitions of risk, the City has matured and new capabilities are now available, and the new format will allow readers to more easily understand the content. In addition, the 2004 HMP included several action items that have been completed, creating an opportunity for developing new mitigation strategies.

9.1 Identify Pandemic Hazards

Pandemics are characterized by the emergence of a new infectious disease that causes serious illness and spreads easily among humans. Since pandemics involve new diseases, there are often no vaccines and little natural immunity to thwart the spread of the epidemic.

Pandemics spread quickly through communities, nationally or even globally. Generally, the elderly, young children, and people with pre-existing illnesses are most vulnerable to a pandemic. However, some pandemics such as the H1N1 Influenza outbreak of 2009 and the Influenza Outbreak of 1918-1919 have defied this pattern by primarily affecting otherwise healthy individuals[91].

Many types of diseases can result in a pandemic. In the 14th century, the Bubonic Plague pandemic in Europe killed around 75 million people in a four-year period.[92] More recently, the Influenza pandemic of 1918-1919 was responsible for millions of deaths worldwide.[93] New, emerging diseases such as Severe Acute Respiratory Syndrome (SARS) or the H1N1 Flu (Swine Flu) are causes for concern. The World Health Organization (WHO) has created a pandemic alert system for influenza-like viruses; shown in **Table 16**.

91 Tara Smith, "Swine flu and deaths in healthy adults--cytokine storm?" Aetiology April 26, 2009, http://scienceblogs.com/aetiology/2009/04/swine_flu_and_deaths_in_health.php.
92 Will Dunham, "Black death 'discriminated' between victims," ABC Science, January 29, 2008, http://www.abc.net.au/science/articles/2008/01/29/2149185.htm.
93 Jeffery Taubenberger and David Morens, "1918 Influenza: the Mother of All Pandemics," Emerging Infectious Diseases 12 no. 3 (2006), http://www.cdc.gov/ncidod/eid/vol12no01/05-0979.htm.

World Health Organization Pandemic Alert System Phases	
Phase 1	No viruses circulating among animals have been reported to cause infections in humans.
Phase 2	An animal influenza virus circulating among domesticated or wild animals is known to have caused infection in humans, and is therefore considered a potential pandemic threat.
Phase 3	An animal or human-animal influenza virus has caused sporadic cases or small clusters of disease in people, but has not resulted in human-to-human transmission sufficient to sustain community-level outbreaks.
Phase 4	Verified human-to-human transmission of an animal or human-animal influenza virus able to cause "community-level outbreaks." The ability to cause sustained disease outbreaks in a community marks a significant upwards shift in the risk for a pandemic.
Phase 5	Human-to-human spread of the virus into at least two countries in one WHO region. While most countries will not be affected at this stage, the declaration of Phase 5 is a strong signal that a pandemic is imminent and that the time to finalize the organization, communication, and implementation of the planned mitigation measures is short.
Phase 6	This Pandemic phase is characterized by community level outbreaks in at least one other country in a different WHO region in addition to the criteria defined in Phase 5. Designation of this phase will indicate that a global pandemic is under way.
Post-Peak Period	Pandemic disease levels in most countries with adequate surveillance will have dropped below peak observed levels. The post-peak period signifies that pandemic activity appears to be decreasing; however, it is uncertain if additional waves will occur and countries will need to be prepared for a second wave.
Post-Pandemic Period	Influenza disease activity will have returned to levels normally seen for seasonal influenza. It is expected that the pandemic virus will behave as a seasonal Influenza A virus.

Table 16: World Health Organization Pandemic Alert System Phases
Source: World Health Organization, "Current WHO Phase of Pandemic Alert," https://www.who.int/csr/disease/avian_influenza/phase/en/.

The primary concern when a pandemic occurs is severe illness and potential loss of life. However, it may have cascading effects on the economy and burden strained existing resources.

A pandemic may cause disruptions in the local economy. Schools and businesses may close either to stop the spread of the disease or due to employee absence. The financial losses due to business closure may be significant. The economic implication of a pandemic is more thoroughly explained in Section 9.3.2.C, Profiling the Vulnerabilities, Systems.

A pandemic will overburden existing services. This will increase emergency response times and demand for health care facilities. In a severe pandemic, public transportation may shut down in order to prevent the spread of diseases. Grocery stores and other service providers may be similarly impacted.

In the event of a pandemic, the WHO and the U.S. Center for Disease Control and

Prevention (CDC) direct response efforts. Depending on the severity of the outbreak, local or national public health agencies may also respond.

9.2 Profiling Pandemic Events

A. Location

All of Redmond is vulnerable during a pandemic. The disease agents (bacteria, viruses, parasites) responsible for a pandemic are more likely to be transmitted in areas with a high human-to-human or human-to-animal contact. Despite Redmond's relatively low residential population density; the large business centers, schools, and retirement homes concentrate large numbers of people. These public gathering places are locations where disease can spread rapidly.

Locations in Redmond that involve large numbers of domestic and international travel, such as hotels or business centers, should be noted as possible locations for the spread of diseases. During the SARS outbreak of 2003, an outbreak of the disease in a hotel was found to be the source of its spread across the globe.[94] Large businesses in Redmond often require extensive business travel outside the region, increasing Redmond's risk of exposure to new diseases.

B. Timing and Duration

Pandemics do not have a predictable time component. The duration of a pandemic may be much longer than many other hazards. The Washington State Department of Health warns, "An Influenza pandemic will most likely not be a short, sharp event leading immediately to commencement of a recovery phase, as would be the case in an earthquake. A pandemic may last several months, as was the case of the 1918 influenza pandemic, and may contain peaks followed by periods of reduced illness."[95]

The ability of local, regional and national medical organizations to prepare for, and respond to, an outbreak will affect the duration of the pandemic. Additionally, the type of disease, number of people infected, and the means by which the disease is transmitted will determine the rate at which the disease will spread. For example, a microorganism that only has the ability to spread via blood contact will spread less quickly than one that has the ability to be transmitted through the air or by contact with contaminated objects.

C. Severity

The severity of a pandemic depends on the disease itself and the method of transmission. A disease that is air-borne and spreads human-to-human could be catastrophic. Once such a disease develops, it has the potential to spread rapidly causing outbreaks around the world, causing many deaths. The CDC predicts that as much as 25% to 30% of the United States' population can be affected by a pandemic

94 World Health Organization, "Communicable Disease Surveillance and Response: Severe Acute Respiratory Syndrome (SARS)," http://www.who.int/csr/media/sars_wha.pdf.
95 Washington State Department of Health, "Pandemic Influenza Planning Guide for State Agencies," http://www.doh.wa.gov/panflu/pdf/StateAgencyPanFluGuide.pdf, 5.

outbreak. In King County that prediction translates to about 540,000 infected people and 11,500 deaths. **Table 17, Selected Diseases, Severity and Method of Transmission**, provides details about previous outbreaks.

Selected diseases, severity and method of transmission						
Disease	Estimated Mortality Rate	Transmission Methods				Notes
		Airborne	Contaminated surfaces	Blood or direct body fluid contact	Animal to Human	
SARS	10%	Maybe	Yes	Yes	Yes	SARS is still considered a rare disease with the last case reported on July 11, 2003.
H1N1 Influenza	0.46%**	Yes	Yes	Yes	Yes	In the past the disease spread to humans mainly via contact with infected pigs. In April 2009, a mutated form that spreads between humans was identified in Mexico. The exact severity of this disease is still under speculation.
Avian Influenza	60%	No	No	Yes	Yes	Frequency of the disease has been low and limited to a few regions around the world due to limited human to human transmission.
Food-borne Illness	minimal	No	No	No	via contaminated food	While food poisoning illness can be severe, outbreaks are limited to people who consumed the infected food source.
Ebola	69%	No	No	Yes	Yes	The spread of Ebola has so far been limited but the virulent nature of this disease is a cause for concern. The virus causes fatal hemorrhaging disease in humans and can be spread via close bodily contact. Some strains of the virus have been demonstrated to be spread airborne between monkeys. A mutation of the disease in the human population could trigger a major worldwide pandemic.
West Nile Virus	3%	No	No	No	Yes	West Nile Virus can only be transmitted to humans via mosquito bites. Frequency of human infection depends on the prevalence of infected mosquitoes. The disease first appeared in North America in 1999, resulting in thousands of flu-like infections throughout the US. It has manifest as fatal encephalitis in certain people.

Table 17: Selected Diseases, Severity and Method of Transmission
Source: Centers for Disease Control and Prevention – Diseases and Conditions http://www.cdc.gov/DiseasesConditions/

** As of June 6, 2009. Calculated from total confirmed cases and deaths. Figure subject to change.

D. Frequency

Previous Occurrences

There are no recent cases of pandemics affecting Redmond directly, but the U.S. has experienced four influenza pandemics in the 20th century. The pandemic of 1918-19 was the most severe pandemic on record, killing 650,000 Americans, and 50 million or more worldwide. The most recent occurrence of influenza pandemic is the 2009 outbreak of H1N1 Influenza (Swine Flu). As of July 6, 2009, 136 countries had officially reported over 94,000 confirmed cases of the influenza infection and 429 deaths.[96]

Probability of future events

King County Health Services Communicable Disease Center warns that in the presence of a growing population, there are more opportunities for infectious diseases to occur and spread. From 2000-2007 Redmond's population increased roughly 10%.[97] The increases in population, paired with increases in international travel, suggest that Redmond is more likely to be affected by a pandemic in the future.

Climate change is another factor that will increase the probability of future pandemics. Rising temperatures enable carriers of disease, such as insects and rodents, to expand their geographic range and thus the ability to infect people.[98] Additionally, milder winters and longer summers increase the ability of warm-climate diseases to survive in previously colder climates. When diseases migrate, the local population will have little immunity to new diseases. Local healthcare providers may have limited knowledge or familiarity with these diseases, and thus be unprepared to diagnose and treat them.[99] These changing variables make it difficult to establish a definite probability for pandemic events.

9.3 Assessing Pandemic Vulnerability

9.3.1 Overview

While a pandemic will not affect man-made structures or the environment, large numbers of fatalities and economic loss may occur. Redmond is home to many large multinational businesses that involve both international and domestic travel, increasing the chances that new infectious diseases may appear there. Redmond contains large numbers of vulnerable populations who may be adversely affected by a pandemic disease outbreak.

96 World Health Organization, "Influenza A(H1N1) - Update 58," http://www.who.int/csr/don/2009_07_06/en/index.html.
97 American FactFinder, "2007 Population estimates," U.S. Census Bureau, http://factfinder.census.gov/servlet/GCTTable?-ds_name=PEP_2007_EST&-mt_name=PEP_2007_EST_GCTT1R_ST9S&-geo_id=04000US53&-format=ST-9&-tree_id=806&-context=gct.
98 Rick Smith, "Is Climate Change Aiding Spread of Disease?" International Herald Tribune, September, 2002, http://news.nationalgeographic.com/news/2002/09/0920_020910_climatedisease.html.
99 Richard Bissel, Andrew Bumbak, Matthew Levy and Patrick Echebi, "The Threat of Infectious Disease in a Global Community," Journal of Emergency Management 7 (2009): 19-35.

9.3.2 Profiling the Vulnerabilities

A. Man-made

The man-made environment, including built structures and infrastructure, is not vulnerable in the event of a pandemic.

B. Natural

While some wildlife may suffer from zoonotic diseases that are transferred between humans and animals, the natural environment is unlikely to be affected as a result of a pandemic.

C. Systems

In the event of a catastrophic pandemic, community systems in Redmond will be severely strained. There are no hospitals within the City limits to treat ill residents; therefore, neighboring jurisdictions are likely to be overwhelmed with patients from Redmond. An increase in deaths resulting from a pandemic may overflow morgues. Medical staff may become ill, resulting in staff shortages. The CDC estimates 540,000 infections in King County could occur during a severe or 1918-level pandemic flu outbreak. This prediction includes 270,000 in need of outpatient care and nearly 60,000 in need of hospitalization. These levels would overwhelm existing regional medical and emergency services.[100]

The economy of Redmond may be severely impacted by loss of productivity, resulting from business closures and isolation. During peaks of a significant pandemic, staff absences could be as high as 50%.[101] Measures to control the spread of diseases could include closing businesses, schools, and public transportation.[102] Even without closures, people with the illness or those in fear of contracting the disease may keep residents away from public areas. Redmond's food supply may be in danger of running short as workers in the food industries fall victim to the disease, impeding delivery of food supplies and depriving people of vital nourishment when their immune systems may be in greatest need of it.[103]

The 2003 SARS outbreak was an example of how a new disease outbreak impacts the economy of the infected countries. Originating in China, the previously unknown disease quickly spread internationally to other Asian countries and North America. International air travel was identified as contributing to its spread.[104] Air travel to SARS-infected areas immediately plummeted due to travel advisories. Tourism and other businesses related to international travel were also affected; a decrease in customers visiting local businesses hurt revenue streams. Special isolation hospitals were dedicated in Hong Kong and Singapore to contain SARS patients. SARS was

100 Public Health- Seattle and King County, "General Questions About Pandemic Flu," http://www.kingcounty.gov/healthservices/health/preparedness/pandemicflu/questions.aspx.
101 Washington State Department of Health, "Pandemic Influenza Planning Guide for State Agencies," http://www.doh.wa.gov/panflu/pdf/StateAgencyPanFluGuide.pdf, 5.
102 U.S. Department of Health and Human Services, "Pandemic Influenza Planning: A Guide for Individuals and Families," (2006). http://www.pandemicflu.gov/plan/pdf/guide.pdf.
103 Berks County Pandemic Advisory Council, "How will the next pandemic affect you?" http://www.co.berks.pa.us/pac/cwp/view.asp?a=3&q=494721&pacNav=%7C34106%7C34108%7C.
104 World Health Organization,"Communicable Disease Surveillance and Response: Severe Acute Respiratory Syndrome (SARS)," http://www.who.int/csr/media/sars_wha.pdf.

transmitted within hospitals, making isolation necessary.

D. Populations

The H1N1 Influenza outbreak of 2009 in Mexico has seen many more fatalities in adults between the ages of 15-50.[105] Although all populations are vulnerable to an outbreak, populations that have increased exposure to viruses or have compromised immune systems are more likely to be infected.

Hazard Specific

People that are exposed to the infected will be particularly vulnerable. Travelers may be more vulnerable to a disease that suddenly appears internationally. Healthcare providers who are treating the infected will have increased contact with the disease and thus will have heightened exposure.

Isolated Populations

If quarantine measures are taken and transit services are reduced in an effort to prevent or slow down the spread of a disease, some people may have difficulty obtaining or accessing goods and services.

Children

Young children, under the age of five, have delicate immune systems that may make them more vulnerable to contract and survive a disease.[106] School children may be more vulnerable due to increased exposure to large populations and inadequate hand washing. Twenty-five percent of Redmond's population consists of children over the age of three that are attending school.[107]

Elderly

People over the age of 65 experience increased risk.[108] Those with existing medical conditions and compromised immune systems are more vulnerable to infection and death. The H1N1 Influenza outbreak of 2009 is an example of a disease that produces only mild symptoms in the majority of people, but may be fatal for those who have asthma, diabetes, or heart disease, illnesses which are common in the elderly.[109] Additionally, like hospitals and schools, the concentration of people in a retirement home increases exposure.

Limited English Language

People who have limited English language skills may have increased difficulty communicating with healthcare providers. This may lead to a delay in diagnosis and treatment. Without prompt identification, the risk of transmission increases and the lack of prompt treatment may cause the case to be more severe. Evidence has shown that current anti-viral drugs may be effective in a pandemic influenza outbreak, but

105 Tara Smith, "Swine flu and deaths in healthy adults--cytokine storm?" Aetiology April 26, 2009, http://scienceblogs.com/aetiology/2009/04/swine_flu_and_deaths_in_health.php.
106 Sam Lister, "Young and Elderly in Danger of Infection," The Times, September 8, 2005, http://www.timesonline.co.uk/tol/news/world/article564087.ece.
107 Census, 2000
108 Sam Lister, "Young and Elderly in Danger of Infection," The Times, September 8, 2005, http://www.timesonline.co.uk/tol/news/world/article564087.ece.
109 http://www.nytimes.com/2009/05/09/health/09flu.html

those drugs must be given at the first signs of the illness. [110]

Low-Income Residents

Uninsured and underinsured people often delay seeking care until symptoms become severe. Delayed diagnosis can increase transmission and decrease treatment effectiveness.

9.3.3 Analyzing Development Trends

Population growth will increase the number of residents who could potentially be exposed to a pandemic disease. An increase in population density may increase the frequency of contact between infected individuals, thus hastening the spread of disease.

110 http://www.nytimes.com/2009/05/09/health/09flu.html

Heat Wave Risk Assessment

This plan is an update of the 2004 City of Redmond Hazard Mitigation Plan (HMP). Although it is an update, this document has been redesigned so that it looks, feels, and reads differently than the original. This is due to several factors: new hazard information has become available that drives new definitions of risk, the City has matured and new capabilities are now available, and the new format will allow readers to more easily understand the content. In addition, the 2004 HMP included several action items that have been completed, creating an opportunity for developing new mitigation strategies.

10.1 Identifying Heat Wave Hazards

A heat wave is commonly defined as a period of abnormal, uncomfortably hot weather. The maximum daytime Heat Index (HI) defines a heat wave by combining temperature with humidity to calculate how hot it feels. Locally, daytime temperatures in the 90s are a problem. Since the Pacific Northwest does not typically experience such extreme temperatures, people do not have air conditioning and bodies are stressed by several days of heat in the 90s or above. Periods that do not cool down at night are particularly harmful. Since the 1970s, an average of three to four deaths occur annually. In 1992, an excessively warm summer was linked to 50-60 deaths.[111]

Heat waves are typically more severe in urban areas with stagnant atmospheric conditions and in areas with high levels of humidity. Heat waves occur every summer in many parts of the United States. Increased high temperatures may also lead to wildfires and drought.

10.2 Profiling Heat Wave Hazard Events

A. Location

In the event of a heat wave, all areas of Redmond will be affected. Redmond's temperate climate and suburban setting are generally not conducive to heat waves. The general lack of residential air conditioning will increase the impacts of irregularly high temperatures.

B. Timing and Duration

Heat waves occur in the summer months and generally can be predicted through weather monitoring. Two consecutive days of temperatures above 90°F triggers the National Weather Service Heat Advisory. Typical hot weather in Redmond is in the low 90°F range and generally lasts for a maximum of four days.[112]

111 National Weather Service, "Heat Wave: A Major Summer Killer," National Oceanic and Atmospheric Administration (NOAA), http://www.nws.noaa.gov/om/brochures/heat_wave.shtml.
112 Office of the Washington State Climatologist, Temperature data from 1999-2008, Courtesy of Karin Bumbaco. Assistant State Climatologist.

C. Severity

According to temperature data from the Office of the Washington State Climatologist, the average Redmond area temperature is 76°F. The highest summer temperatures in 2000-2008 in the Redmond area are displayed in Figure 7. In 2006 and 2007, Redmond experienced historic highs of 95°F.[113] Redmond's record high temperature is below the National Weather Service's alert temperature of 105°F. However, due to the generally mild climate, several days in the 95°F range would have a significant impact on the City.

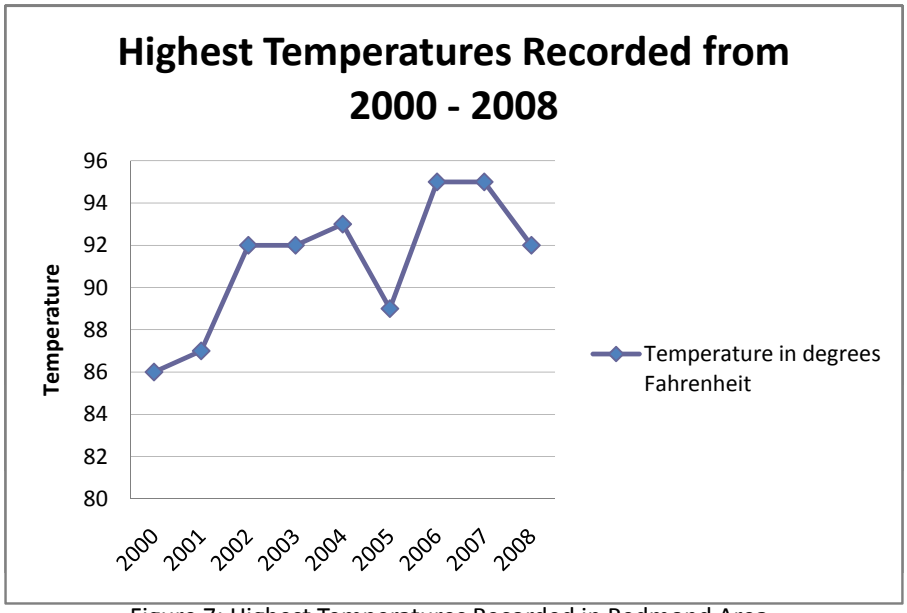


Figure 7: Highest Temperatures Recorded in Redmond Area
Source: Data from the Office of the Washington State Climatologist

D. Frequency

Previous Occurrences

Redmond has never experienced a heat wave as defined by the National Weather Service. However, Redmond has experienced temperatures in the upper 90s that have lasted for several days, in both 1992 and in 2009, with a new record high temperature of 103 degrees.

Probability of Future Events:

Climate change trends will increase the number of hot weather days in Redmond. Predictions indicate that average temperatures will increase 2°F by 2020.[114] Temperature fluctuations will be more extreme, potentially increasing temperatures in the Redmond area to higher levels that would trigger a National Weather Service alert. Climate change information also suggests that increasing temperatures will affect urban and rural areas similarly. In the future, Redmond may not be insulated from heat waves as it has been in the past.[115]

10.3 Assessing Heat Wave Vulnerability

113 Ibid.
114 Climate Impacts Group, "Climate Change Scenarios," University of Washington, http://cses.washington.edu/cig/fpt/ccscenarios.shtml#caveats.
115 Climate Impacts Group, "Climate Change Scenarios," University of Washington, http://cses.washington.edu/cig/fpt/ccscenarios.shtml#caveats.

10.3.1 Overview

Currently, extremely high temperatures are rare in the Pacific Northwest and thus Redmond is not particularly vulnerable. However, as the climate changes, heat waves are an anticipated hazard. In the event of a heat wave in Redmond, human populations, the natural environment and energy systems may be affected. Since Redmond is unaccustomed to heat waves, temperatures in the 90s may have impacts, even though such an event would not trigger a National Weather Service alert.

10.3.2 Profiling the Vulnerabilities

A. Man-made

Built structures are not vulnerable to heat waves.

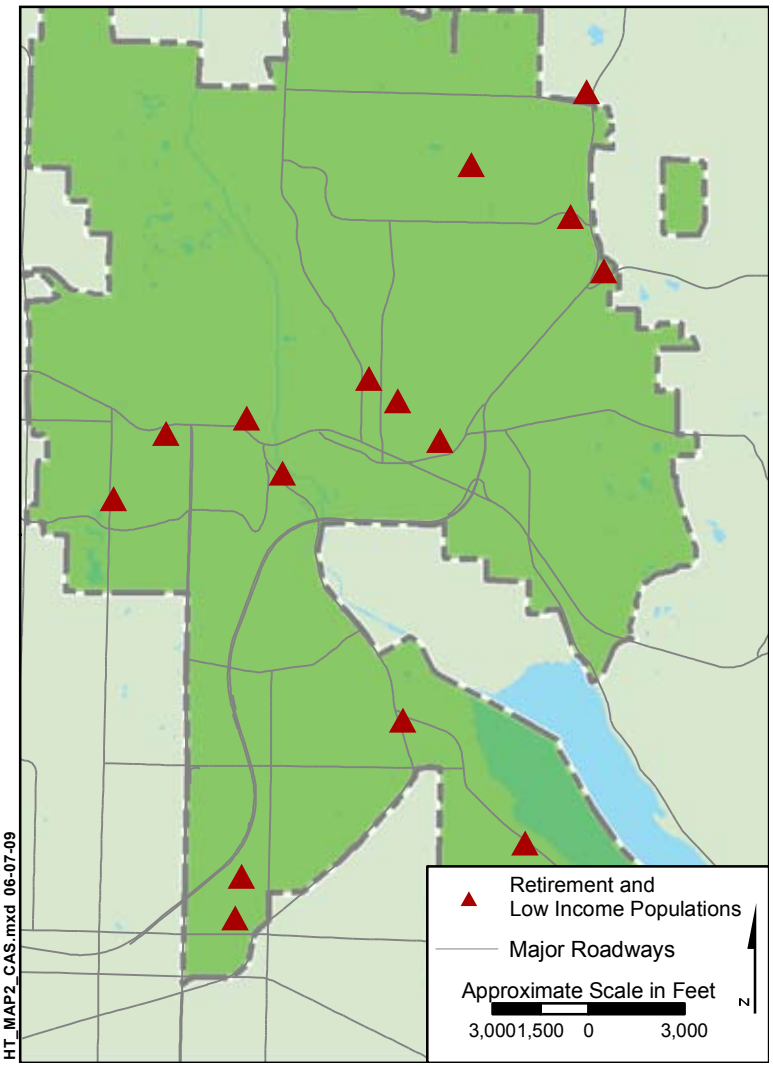
B. Natural

In the event of a heat wave, some crop growth may be impacted if the heat occurs during the plant's early development stages. If a drought accompanies a heat wave, water shortages will impact crop and other vegetation growth. Extreme high temperatures may also increase the likelihood of wildfires. Heat waves can increase temperatures in streams and rivers, which could lead to changes in migration timing, reduce growth rates and reduce available oxygen for local fish species.[116]

C. Systems

Extremely high temperatures will increase water usage. The water supply is vulnerable to overuse during a heat wave. High temperatures can soften of asphalt or buckle concrete. Such damage to the roadways would lead to regional transportation problems.[117]

Retirement Homes and Low Income Populations
Source: King County



Map 32: Retirement Homes and Low Income Populations

D. Populations

The body cannot easily compensate with overexposure to heat. Heat-related illnesses include fatigue, dehydration, heat

116 National Wildlife Federation,"A Great Wave Rising: Solutions for Columbia and Snake River Salmon in the Age of Global Warming," http://www.nwf.org/GlobalWarming/pdfs/AGreatWaveRising.pdf.
117 Cooperative Institute for Research in the Atmosphere, "Impacts of Temperature Extremes," http://sciencepolicy.colorado.edu/socasp/weather1/adams.html.

exhaustion and heat stroke. In a normal year, about 175 Americans die from the summer heat.[118]

Hazard Specific
People without access to cooling devices such as air conditioning may be more vulnerable during a heat wave.

Isolated Populations
Since there will be little structural damage during a heat wave, people will not become isolated.

Disabled Persons
Disabled persons with compromised immune systems may have an increased risk.

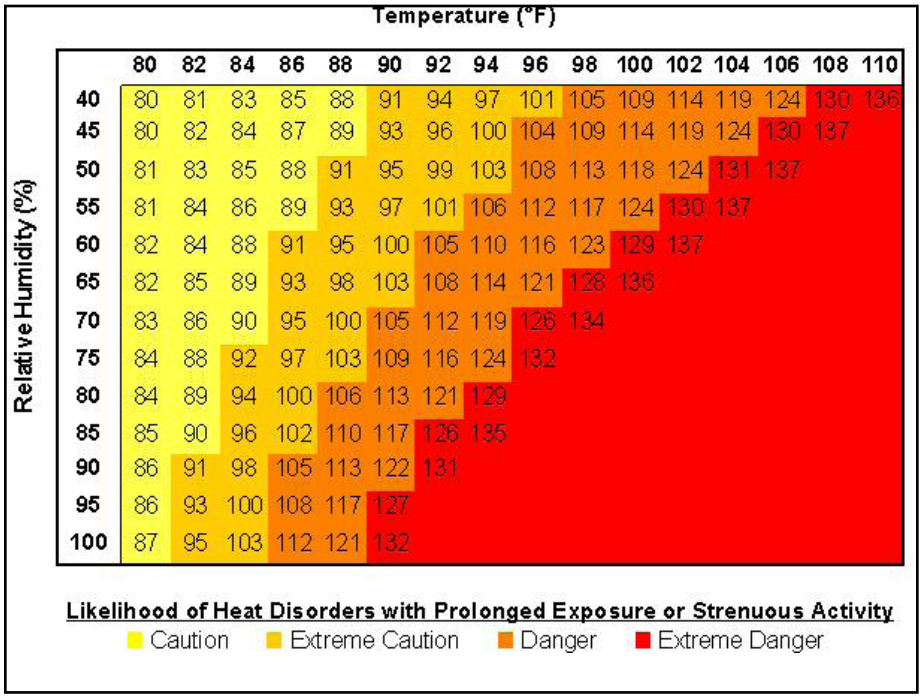


Table 18: Likelihood of Heat Disorders Based on Temperature and Relative Humidity
Source: National Oceanic and Atmospheric Administration, "National Weather Service Heat Index," http://www.nws.noaa.gov/om/heat/index.shtml.

Elderly
High temperatures require the human heart to work harder to pump blood toward the skin to help regulate body temperature. Elderly populations, especially those with heart conditions, will be more impacted by heat waves.[119]

Limited English Language
Non-English speaking populations will not be particularly vulnerable to heat waves.

Low-income Residents
Low-income residents may be more impacted by heat waves if they do not have access to air-conditioning.

10.3.3 Analyzing Development Trends

Development and paved surfaces increase local surface temperatures. Urban areas create localized "heat islands"; increased development in Redmond will amplify this effect. If heat waves are accompanied by water shortages, population increases will correlate to water demand.

118 National Weather Service, "Heat Wave: A Major Summer Killer," National Oceanic and Atmospheric Administration (NOAA), http://www.nws.noaa.gov/om/brochures/heat_wave.shtml.
119 Cooperative Institute for Research in the Atmosphere, "Impacts of Temperature Extremes," http://sciencepolicy.colorado.edu/socasp/weather1/adams.html.

Drought Risk Assessment

This plan is an update of the 2004 City of Redmond Hazard Mitigation Plan (HMP). Although it is an update, this document has been redesigned so that it looks, feels, and reads differently than the original. This is due to several factors: new hazard information has become available that drives new definitions of risk, the City has matured and new capabilities are now available, and the new format will allow readers to more easily understand the content. In addition, the 2004 HMP included several action items that have been completed, creating an opportunity for developing new mitigation strategies.

11.1 Identifying Drought Hazards

A drought is an extended period (usually one or more seasons) of abnormally low precipitation. It is a condition of climate dryness severe enough to reduce soil moisture, water and snow levels below the minimum level necessary for sustaining normal plant life, animal life, and economic systems. Droughts are often exacerbated by overuse of the water supply by residents. Secondary effects that may result from drought may include fire, landslides and economic impacts.[120]

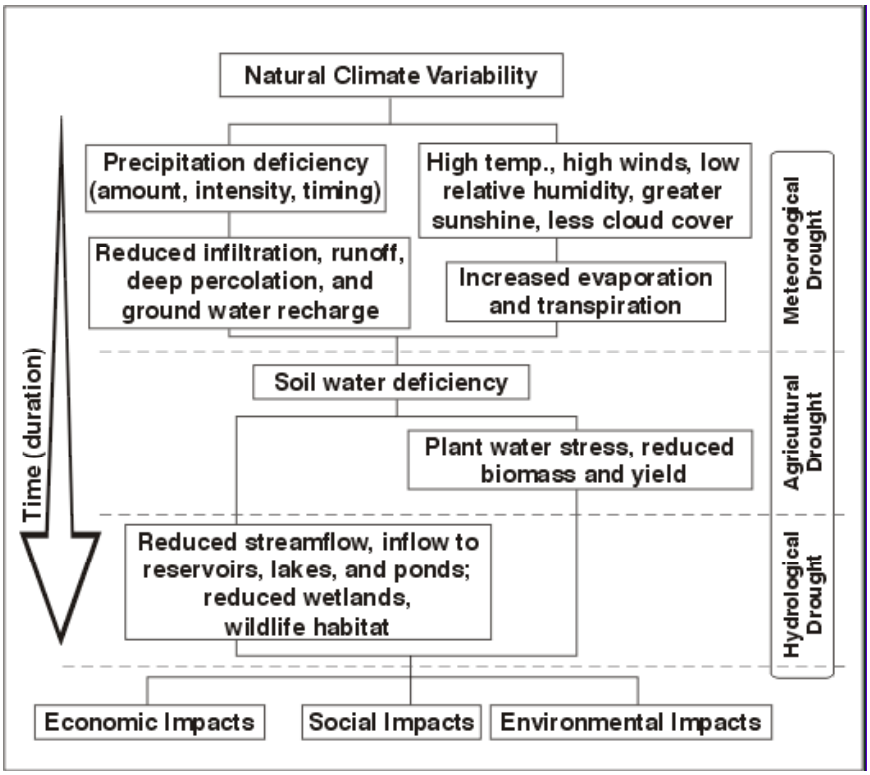


Figure 8: Concept of Drought
Source: National Drought Mitigation Center, "Concept of drought."

In 1989, the Washington State Legislature gave permanent drought relief authority

120 National Drought Mitigation Center, "What is Drought," University of Nebraska, Lincoln. http://drought.unl.edu/whatis/concept.hmtl.

to the Department of Ecology and enabled them to issue orders declaring drought emergencies (RCW 43.83B.400-430 and Chapter 173-166 WAC). In order to declare a drought in the State of Washington, two characteristics must be met:

- The water supply for the area must be below 75% of normal levels
- Water uses and users in the area must be likely to incur undue hardships because of the water shortage.[121]

60% of the water used by Redmond comes from the Cedar and Tolt watersheds, supplied by Seattle Public Utilities (SPU). The watersheds provide potable water to numerous cities in King County. The reservoirs have a limited capacity and therefore, large rain events in the winter do not necessarily prevent summer droughts. The reservoirs must be continually fed by rain and snowmelt to have an adequate supply. Redmond does not have direct control over the amount of water it will be allotted during times of drought and must share a drought's impact among numerous other cities.[122]

The other 40% of Redmond's water is supplied by five main groundwater wells located in the City. [123] The wells are recharged by rain. During a drought that lasts for a short period, Redmond's groundwater supply may incur no significant changes; however, water stored in soil can be rapidly depleted during extended dry periods. Additionally, when drought conditions abate, groundwater takes longer to recover than soil water reserves, stream-flow, reservoirs and lakes.[124]

121 Washington State Legislature, "Revised Code of Washington," http://apps.leg.wa.gov/RCW/.
122 Seattle Public Utilities, "Cedar and Tolt Watersheds,"City of Seattle, http://www.seattle.gov/util/About_SPU/Water_System/Water_Sources_&_Treatment/index.asp.
123 City of Redmond, "Drinking Water," City of Redmond, http://www.ci.seattle.wa.us/util/About_SPU/Water_System/Water_Supply/SPU01_001850.asp.
124 City of Redmond, "Wellhead Protection," City of Redmond, http://www.redmond.gov/insidecityhall/publicworks/environment/groundwaterordinance.asp.

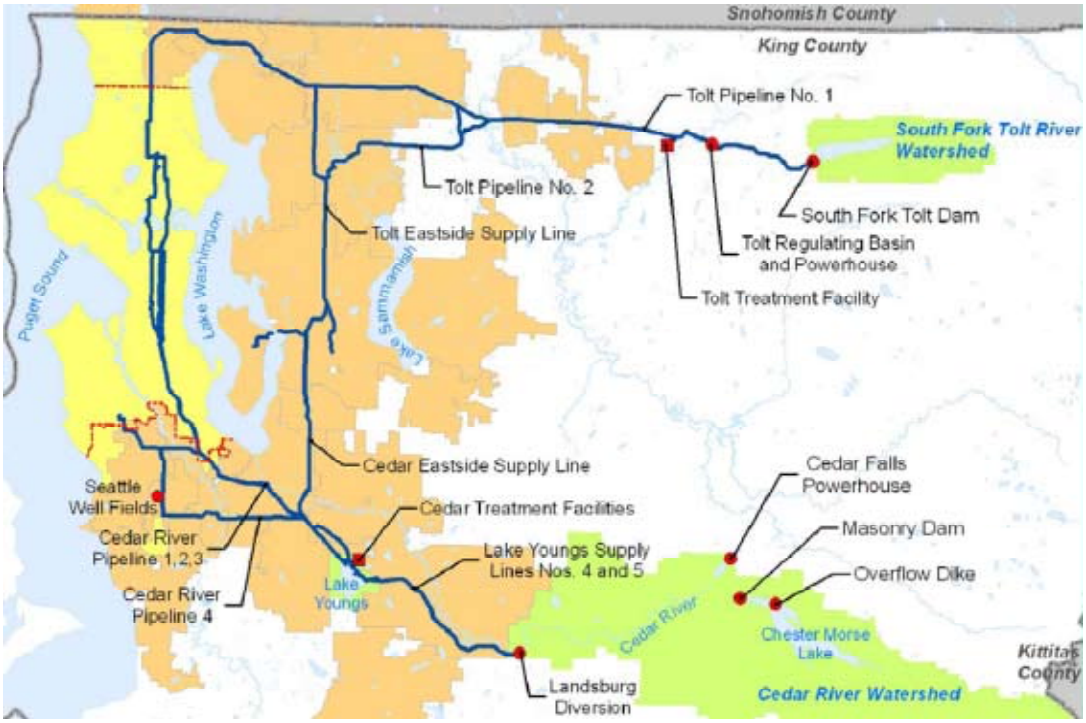


Figure 9: South Fork Tolt Water Management Plan
Source: Seattle Public Utilities, "South Fork Tolt Water Management Plan".

11.2 Profiling Drought Hazard Events

A. Location

Since the whole City of Redmond relies on shared water sources, the entire City will be affected by a drought. Past droughts in the Puget Sound Region have resulted in water use restrictions and higher water charges. Redmond business and residents were consequently unable to adequately maintain landscaping. Water shortages cause loss of vegetation, including the 1,300 acres of parks located in the City.[125]

B. Timing and Duration

A short-term drought lasts anywhere from three to six months while long-term droughts can last for several years.[126] Given the history of drought in the Puget Sound region, it is likely that any drought that would affect Redmond would only last for a short period, taking place in spring and/or summer months, and would be easily forecast well before it occurred.

C. Severity

Droughts in the Pacific Northwest are likely to: reduce potable water supplies, provide inadequate stream flow volumes to support fish, increase the threat of wildfires, and pose a threat to vegetation that relies on natural precipitation. The severity of a

125 City of Redmond, "About Redmond," City of Redmond, http://www.redmond.gov/aboutredmond/general2.asp.
126 National Drought Mitigation Center, "What is Drought?" University of Nebraska, Lincoln, http://drought.unl.edu/whatis/concept.hmt.

drought can be reduced by water conservation technology and practices. The length of the recovery period is determined by the intensity of the drought, duration, and quantity of precipitation received as the drought recedes.[127]

In 2001, Seattle Public Utilities decreased the risks associated with a drought to its users and the salmon runs through designed, monitored, and implemented water conservation tactics.[128]

D. Frequency

Previous Occurrences
Since 1900, about fifteen droughts of various durations have affected the Puget Sound Region, the most recent droughts occurred in 2001 and 2005[129].

King County Office of Emergency Management lists the most significant droughts affecting the Puget Sound region in the past thirty-five years as:

- **1965-1966:** The entire State was affected by drought conditions from June 1965 to December 1966.
- **June-August 1967:** No rain fell from the third week in June to the third week in September. 1,767 fires burned throughout the State.
- **October 1976-September 1977:** King County experienced precipitation levels 57 percent of normal. Stream flows averaged between 30 and 70 percent of normal. Temperatures were higher than normal, which resulted in algae growth and fish kills.
- **October 1991-September 1994:** Stream flows were between 30 and 60 percent of normal. Agriculture products suffered greatly. Thirty counties were designated as Emergency Drought Impact areas.
- **March of 2001:** The National Weather Service reported that the winter of 2000-01 was the driest since 1976-1977. It was also one of the five driest in the past 100 years.[130] Following above-average precipitation in the final two months of the year, the drought emergency formally expired on December 31, 2001.

Probability of Future Events
The possibility of drought affecting Redmond is moderate based on historical records. Seattle Public Utilities does provide a document titled "Current Water Supply Conditions and Outlook." Based on the history of drought in Puget Sound and Washington State there is a risk that some form of drought will affect Redmond at least once each decade, though the impacts may be mild. The frequency, duration and depth may increase with climate change.[131]

127 King County Office of Emergency Management, "Natural Hazards: Droughts," King County, http://www.kingcounty.gov/safety/prepare/residents_business/Hazards_Disasters/Droughts.aspx.
128 Seattle Post Intelligencer, "Seattle Drought Efforts Pay Off," Seattle Times, http://www.seattlepi.com/local/37701_drought05.shtml.
129 Puget Sound Business Journal, "Drought: Dry weather of 2005 drains reservoirs and ruins orchards," Puget Sound Business Journal, http://seattle.bizjournals.com/seattle/stories/2005/08/01/story2.html
130 King County Office of Emergency Management, "Natural Hazards: Droughts," King County, http://www.kingcounty.gov/safety/prepare/residents_business/Hazards_Disasters/Droughts.aspx.
131 National Center for Atmospheric Research, "Drought & Wildfire," http://www.ncar.ucar.edu/research/climate/drought.php.

While King County is not on Washington State's list of jurisdictions most vulnerable to drought, nor is it a critical area for drought according to the National Drought Mitigation Center; the historical record of both Western Washington and the State demonstrates that it is important to consider drought conditions as a potential impact to the region. Climate change will change the patterns of precipitation and the expanse of arid regions.[132] Even without changes in the overall quantity of precipitation, rain replacing snow will cause shortages in the summer water supply.

11.3 Assessing Drought Vulnerability

11.3.1 Overview

Western Washington and Redmond's economy are vulnerable to droughts. Reduced water supply will have an impact on the systems and people that require water. Reduced stream flows will impact wildlife and hydroelectric power. Landscapes, natural habitats, vegetation, and area parks and trails will be vulnerable.[133]

11.3.2 Profiling the Vulnerability

A. Man-made
Droughts have no significant impact on man-made structures. Lawns, gardens, and other human-manipulated landscapes and vegetation such as golf courses are vulnerable to droughts.

B. Natural
Drought may reduce stream flows, which will impact aquatic life and ecosystems that are dependent on the stream. Low stream flows will increase water temperatures affecting the migration and reproduction habits of salmon and trout.[134] A drought may also lead to insufficient recharge of aquifers, creating water shortages. Decreased precipitation will increase the likelihood of wildfires, as dry trees and brush have an increased risk of burning.

C. Systems
Reduction of available water in reservoirs intensifies the debate over water allocation among agricultural irrigators, municipal water authorities, environmental agencies, and industrial users. Additionally, water quanitity affects the availability and cost of electricity since Puget Sound is heavily reliant on hydroelectric power plants. The water supply and energy supply are vulnerable to a drought.

Drought will impact all populations in Redmond. Specific businesses that require larger portions of water to run their business (carwashes, golf courses, etc.) will be especially vulnerable if they do not have mitigation strategies in place to withstand the

132 International Panel on Climate Change and University of Washington Climate Impact Group, "Climate Change Scenarios," University of Washington, http://cses.washington.edu/cig/fpt/ccscenarios.shtml.
133 Seattle City Light, "Water Conditions: Rainfall and Snowpack," City of Seattle, http://www.seattle.gov/light/ctracks.html.
134 Washington Department of Fish and Wildlife, "Drought Planning," http://www.wdfw.wa.gov/drought/.

shortage. Additionally, increased electricity charges could place economic hardships on small businesses, and businesses that consume larger amounts of energy.

D. Population

Droughts will impact the entire region. Unless water restrictions are not sufficient to ration enough potable water to meet basic necessities, no specific populations will experience heightened vulnerability. However, the resulting increased electricity and water rates may be and economic hardship for limited income residents.

11.3.3 Analyzing Development Trends

The City of Redmond water system currently serves a residential population of approximately 51,530 and a business community with an estimated 85,775 employees.[135] Redmond does not have additional water supplies and their water service area is fixed. Future growth in the area will be limited to the water sources and sewer infrastructure currently available. Without conservation efforts, increased population in the area will strain water and sewer resources.

135 City of Redmond, "About Redmond," City of Redmond, http://www.redmond.gov/aboutredmond/general2.asp.

Hazardous Materials Risk Assessment

This plan is an update of the 2004 City of Redmond Hazard Mitigation Plan (HMP). Although it is an update, this document has been redesigned so that it looks, feels, and reads differently than the original. This is due to several factors: new hazard information has become available that drives new definitions of risk, the City has matured and new capabilities are now available, and the new format will allow readers to more easily understand the content. In addition, the 2004 HMP included several action items that have been completed, creating an opportunity for developing new mitigation strategies.

12.1 Identify Hazardous Materials Hazards

The EPA defines hazardous materials as liquid, solid, contained gas, or sludge wastes that contain properties that are potentially harmful to human health or the environment.[136] Hazardous materials are typically released in the form of spills, leaks, or vapor emissions. These are known as either a point source release that can be traced back to a single origin, or non-point source releases that occur incrementally, slowly polluting the environment.

Non-point source hazardous materials are difficult to track and control. Facilities that contain large quantities of hazardous materials are regulated to reduce the risk of point source spills. These facilities are categorized as Tier II facilities, which are defined as those that equal or exceed the thresholds of hazardous materials listed under Section 311(e) of Title III of the Superfund Amendments and Reauthorization Act (SARA).[137]

Tier II facilities are required to complete a Tier II Emergency and Hazardous Chemical Inventory report by The Washington State Emergency Response Commission (SERC). These facilities are also required to report to the Local Emergency Planning Committee (LEPC), and local fire department. Tier II storage facilities are required to comply with federal safety requirements and are regulated by the U.S. Environmental Protection Agency.

12.2 Profiling Hazardous Materials Hazard Events

A. Location

Both point source and non-point source pollution is likely to occur where hazardous materials are located. **Map 33, City of Redmond Tier II Hazardous Material Facilities,** shows the location of all facilities that keep significant amounts of chemicals on site. Point source releases are more easily identified. While non-point source pollution can also occur where hazardous materials are present, such releases may not be

136 U.S. Environmental Protection Agency, "Wastes–Hazardous Waste," http://www.epa.gov/osw/hazard/index.htm.

137 Emergency Planning and Community Right-to-Know Act (EPCRA), "Hazardous Chemical Storage Reporting Requirements," U.S. Environmental Protection Agency, http://www.epa.gov/oem/content/epcra/epcra_storage.htm.

immediately recognizable. Both types of releases can occur either on location where the hazardous materials are stored, or along transportation routes.

The Olympic Pipeline is another potential source for a hazardous material spill. Located along the western edge of the City of Redmond, it transfers millions of gallons of jet fuel, gasoline or diesel daily.

B. Timing and Duration

The time component of point source hazardous materials incidents can range from hours to days. Factors contributing to the duration and subsequent severity of hazardous materials events are the ability of local and/or regional transportation agencies, incident response, and toxic chemical handlers to respond to the event. Non-point source hazardous material release occurs slowly over an extended period of time.

C. Severity

According to the U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration (PHMSA), hazardous materials are most dangerous when they are first released from containment, and the severity of an event depends on the chemical and biological components of the material released.[138] A significant number of Tier II facilities in Redmond hold supplies of sulfuric acid or gasoline/diesel. Sulfuric acid is described as "more hazardous than most chemicals" by 7 out of 10 ranking systems and is one of the most prolific chemicals produced in the United States. However, an extensive web of federal, state, and local regulations effectively limits the probable impacts and severity of a point source hazardous materials incident.

D. Frequency

Previous Occurrences

Sulfuric acid is listed as the second most common Tier II hazardous material in Redmond. There have been no reported point-source releases of the Tier II hazardous material, sulfuric acid, in Redmond (zip codes: 98052, 98053, 98073).[139] No point-source releases of any Tier II chemicals previously been reported in Redmond. Non-Tier II point-source releases are unknown, and are more difficult to identify due to less stringent regulation than Tier II hazardous materials. Non-point source releases are not monitored, and therefore no records exist of their previous occurrences.

Probability of Future Events

An increase in hazardous material facilities due to the projected growth of the City will increase the potential for both point source and non-point source events.

138 U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration. "Incident Reporting." http://phmsa.dot.gov/hazmat/incident-report

139 Environmental Defense Fund, "Scorecard, the Pollution Information Site," http://www.scorecard.org.

12.3 Assessing Hazardous Materials Vulnerability

12.3.1 Overview

Although there are numerous sites in Redmond that contain sizable amounts of Tier II hazardous materials, the stringent regulations for handling, storage, transport, and recording of Tier II hazardous materials and related facilities limit the vulnerabilities. However, the presence of toxic chemicals does present a great risk to the human population and the environment.

12.3.2 Profiling the Vulnerabilities

A. Man-made
Buildings are vulnerable to a hazardous materials spill. The combination of fire, water and chemicals could result in an explosion that is likely to damage both the buildings storing hazardous materials and neighboring buildings. Proper storage and handling of these chemicals is critical in decreasing built environment vulnerability.

B. Natural
Factors contributing to the vulnerability of natural systems are the type of chemical spilled, the physical state of the chemical, the amount released, and the location of the incident. Vulnerability of the natural environment to hazardous materials events is higher for species and ecosystems in the immediate vicinity of the event, and moderate for those located downstream. Over time, non-point source hazards may accumulate and pose a threat to the natural environment; however, the lack of data on non-point source hazards makes it difficult to justify a significant vulnerability.

C. Systems
A hazardous materials spill anywhere along Redmond's transportation network will have an immediate impact on travel time and delays. A flammable material that explodes would cause significant damage to the roads and bridges. Similarly, an explosion could destroy power lines.

Municipal water systems and stormwater drainage systems are vulnerable to a toxic spill. Chemicals that reach the water system could limit the supply of potable water. Toxic spills that enter a stormwater drainage system may feed directly into local rivers and lakes or into the groundwater.

D. Populations

Hazard Specific
Populations in close proximity to a spill will be particularly vulnerable.

Isolated Populations
The City of Redmond is particularly vulnerable to isolation in the event of a hazardous material spill occurring on a major arterial roadway connecting to the greater Puget

Sound region. A spill that closes or destroys part of SR 520 would leave much of Redmond isolated from the surrounding region.

Disabled Persons
Mobility impaired persons would be vulnerable to a spill or vapor release that requires immediate evacuation. Similarly, people with hearing or sight impairments may require special notification if the standard announcements are not available.

Children
Young children with developing respiratory systems are especially vulnerable to a chemical vapors.

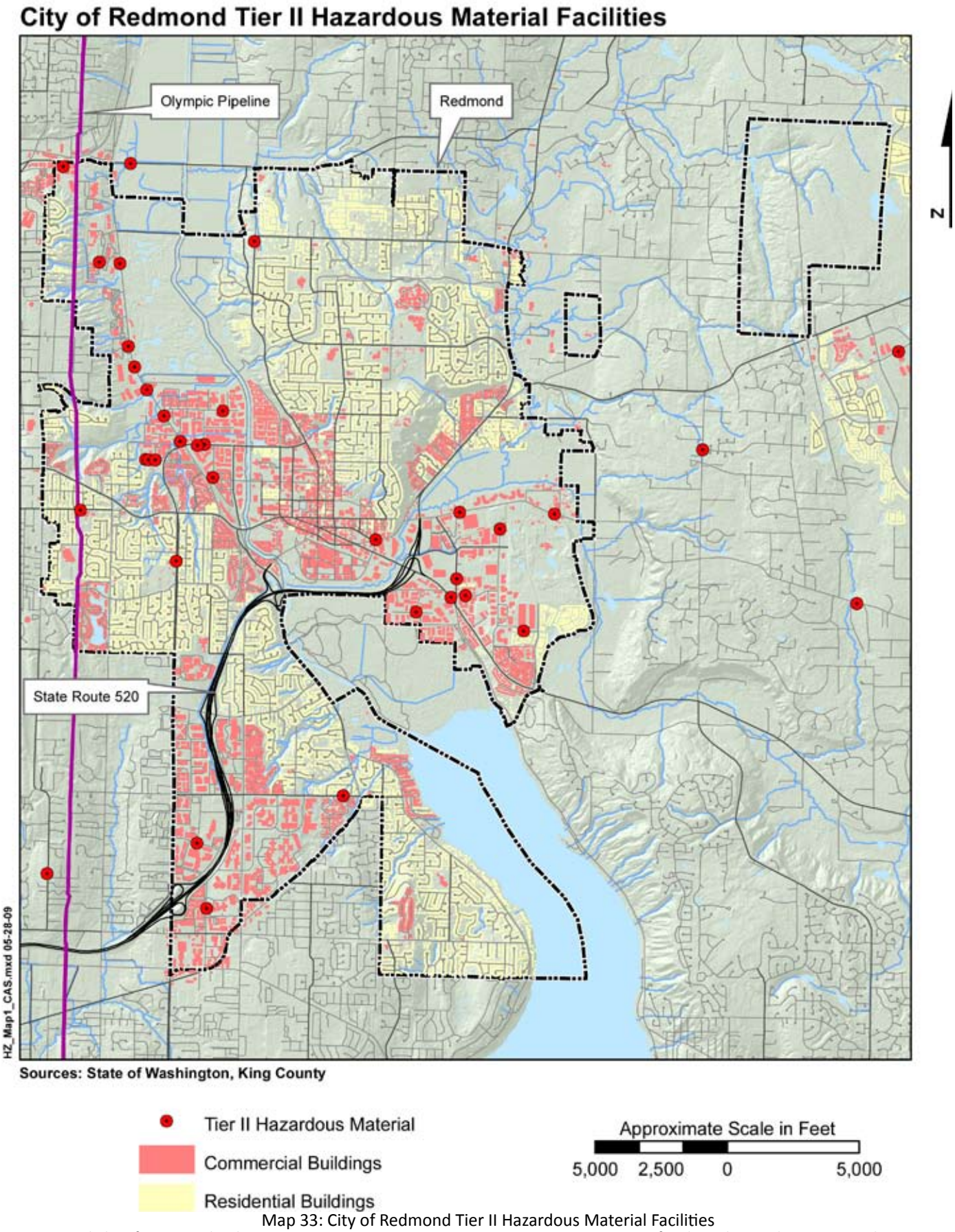
Elderly
Elderly with mobility impairments or compromised immune systems may suffer greater injuries in the case of a hazardous material release.

Limited English Language
Limited English speakers may not have immediate information about a spill without translation. Additionally, access to appropriate aid may be complicated by language barriers.

Low-income Residents
Low-income citizens are more likely to reside in closer proximity to hazardous facilities than wealthier counterparts. If displaced by a hazardous materials spill, limited income residents may face additional hardship.

12.3.3 Analyzing Development Trends

A vast majority of existing Tier II facilities are located within industrial and manufacturing areas. The future land use map shows maintenance of similar zoning in areas where the highest concentrations of Tier II facilities are currently located. However, continued automobile dependency may increase the number of gas stations (Tier II facilities) in proximity to residential areas. The addition of wireless telecommunications will increase the number of Tier II facilities near residential areas.



Map 33: City of Redmond Tier II Hazardous Material Facilities

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